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ADAPTATIONS TO AQUATIC, ARBOREAL, FOSSORIAL AND CURSORIAL HABITS IN MAMMALS.

III. FOSSORIAL ADAPTATIONS.

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THE purpose of the following article is to summarize a few of the principal modifications in external shape and in the skeleton independently acquired by mammals in different orders which have become wholly or partially adapted to a life beneath the surface of the ground. The highest specialization in this direction is found, as we should expect, in those forms which secure not only safety but also their food within the earth (*e. g.* the moles). Such forms are completely fossorial. On the other hand the procuring of food above ground and the use of the burrow merely as a safe place in which to live and rear young requires fewer fossorial modifications, and such forms may be called semi-fossorial, although, naturally, between fossorial and semi-fossorial no fixed line can be drawn. The following characters are best seen in the truly fossorial forms.

A. EXTERNAL MODIFICATIONS.

1. *Body more or less fusiform.*— An obvious adaptation to progression in such a dense medium as earth. In the common mole (Condylura), for example, the body-diameter is greatest at the shoulder, and diminishes gradually to a point at the nose. In some fossorial forms, *e. g.* the wombat (Phascolomys) and woodchuck (Arctomys), the body is very thick.

2. *Eyes imperfectly developed or obsolete.*— Normally developed eyes are traditionally useless to an animal living in complete darkness, and would be a continuous source of pain from injury received in burrowing. The degree of degeneration is no doubt partly dependent on the length of time which has elapsed since the assumption of fossorial habits, and on the relative completeness of withdrawal from the upper air. In the pocket gophers (Geomyidæ) and Bathyergidæ the eyes are small; in *Spalax typhlus* they are mere black specks among the muscles (although retaining a relatively complete structure); in the marsupial mole (*Notoryctes typhlops*) they are imperfectly developed and functionless; in Talpa they are vestigial; in the Cape golden mole (Chrysochloris) the eyes are covered with skin.

3. *External ears, small, tending to disappear.*— External ears impede burrowing especially as they are situated at the upper and anterior part of the body where much friction would naturally occur. Hence in the Geomyidæ and in Lutra the external ears are small, in the ratel (Mellivora) very minute and in the Bathyergidæ they have become reduced to a mere ring of skin around the auditory aperture, while in Notoryctes, Chrysochloris and Talpa they are absent.

4. *Limbs short and stout.*— Since in a truly fossorial animal strength to dig is of more importance than swiftness of progression on the surface of the ground the limbs are short and stout (Ornithorhynchus, Echidna, Talpa, etc.). This of course does not hold good for the majority of semi-fossorial forms, as in their life above ground they need speed either to get food or to escape enemies. Many of these, however, as our common wood-

chuck (*Arctomys monax*) and the wombat (Phascolomys), have legs quite short and stout; while for example in the pig-footed bandicoot (*Chœropus castanotis*) the legs are long and cursorial in type. In the latter animal the external ears are also very long.

5. *Manus broad and stout, with long claws.*— The fore feet and hind feet have undergone divergent specialization, since the fore feet are used to loosen the earth, while the hind ones merely throw it further backward. Hence the manus becomes broad and stout with very strong claws. In the common mole (Condylura) the manus is as broad as the whole body, and hence it can dig with exceeding rapidity, excavating with one sweep of the arm a place wide enough for entrance. In Echidna also the manus is broad. The enlarged strong claws are well seen in Notoryctes, Phascolomys, Taxidea and the Geomyidæ.

6. *Pes modified to throw the loose earth backward.*— The pes has the claws well developed although not nearly so strongly as in the manus. Some animals have developed special adaptations for throwing back the loose earth. In Phascolomys the second, third, and fourth digits are partly connected by skin. This web is of course strongly developed in such swimming forms as Chironectes and Scalops but it is also a great aid to them in burrowing. Heterocephalus has the feet fringed with stiff hairs, while the Octodontidæ have long stiff hairs at the roots of the claws. The hallux is at times vestigial as in Phascolomys.

7. *Tail usually short.*— A tail seems to be a useless appendage to an animal surrounded closely by earth so it becomes quite short even in many semi-fossorial forms as in the hare, ratel, and woodchuck. In the wombat, moles, etc., it is vestigial. Oryzoryctes is an exception, for although fossorial it has a comparatively long tail.

B. Skeletal Modifications.

1. *Skull in top view triangular, apex forward.*— The subconic form of the skull is one of the obvious adaptations to progression through a dense medium. It is very well seen in Condylura, *Crossopus fodiens*, etc.

2. *Zygomatic arches not extended outside the greatest width of the skull.*— All projections from the usual regularly shaped skull become reduced. The zygomatic arches are very slender (*e. g.* Condylura, Talpa, Erinaceus, Orycteropus).

3. *Prenasal ossicle.*— A small prenasal ossicle is developed at the tip of the mesethmoid cartilage in Talpa as it is in the pig (Sus), due doubtless to the same cause, that of using the nose as an aid in digging.

4. *Incisor teeth chisel-shaped, projecting forward.*— In some forms the large incisors serve to keep earth out of the mouth, in others they are used as an aid in digging. The wombat (Phascolomys) for example has a pair of strong chisel-shaped projecting lower incisors. Among the rodents *Spalax typhlus* for example has the well developed lower incisors projecting beyond the lower jaw; the bamboo rat (Rhizomys) uses its incisors to aid in digging, in the Bathyergidæ the entrance of earth is prevented by the upper incisors which extend in front of the closed lips.

5. *Cervical and lumbar vertebræ more or less fused.*— The fusion of these vertebræ gives strength and firmness in pushing (*e. g.* Notoryctes and the armadillos). It is possible that the peculiar intercentral ossicles observed below the lumbar vertebræ especially in Talpa and the Erinaceidæ may be of use in strengthening the spinal column. Phascolomys and the Dasypodidæ have the cervical vertebræ wide and depressed; in the latter several of them are commonly anchylosed. In Talpa, the fourth, fifth and sixth cervicals are much lengthened and overlap each other.

6. *Transverse processes of lumbar vertebræ very short.*— Since in truly fossorial forms there is but little up and down or from side to side movement in the lumbar region, the corresponding muscles and their attachments, the transverse processes are feebly developed (*e. g.* Erinaceus).

7. *Sacrals fused.*— The main stress in pushing comes on the sacrals; in the majority of fossorial forms (*e. g.* Condylura, Lepus) they fuse even to a greater extent than in cursorial animals, as no lateral or vertical displacements but only rigidity are required of them.

8. *Sternum well developed.*— The anterior part of the trunk requires rigidity, great strength and ample surfaces for the attachment of the hypertrophied digging muscles. The individual bones tend to become short and broad and the processes for muscular attachment prominent (*e. g.* armadillos). In the moles change of position of the fore limb is correlated not only with the broadening but especially with the elongation of the presternum; at the same time the clavicle is extremely broad, and shortened so that the limbs may project as little as possible from the sides of the body; the limbs are but slightly shortened, so that the leverage of the muscles is unaffected. In Chrysochloris this need is met by the invagination, as it were, of the walls of the thorax for the reception of the arms, the ribs and sternum being convex inward. The clavicle is usually, as in Chrysochloris, curved backward from the sternum, so that the shoulder may slope gradually forward and not be an angular projection interfering with progress through the earth.

9. *Bones of fore limb strong, tuberosities prominent.*— The fore limbs being the principal organs for digging are well developed, while the tuberosities, ridges, etc., for the insertion of muscles are very prominent. Sesamoid bones are frequently developed in the palms, as in Echidna where also the breadth of the hand is increased by a radial sesamoid (os falciforme of Talpa). The humerus is usually stout and broad as in Talpa, Phascolomys, Echidna, etc., with prominent deltoid and supinator ridges. These are carried to an extreme in Talpa where the deltoid ridge joins the inner tuberosity above. The olecranon process is always strongly developed. A supracondylar foramen is usually present.

10. *Ilium and ischium rod-like, parallel to the vertebral column and fused to the sacrum.*— The hind limbs being mainly used for pushing the body through the earth, their point of attachment to the body must be firm and they must deliver the forward thrust in a more or less horizontal plane. So we find that the ilium is long and fused usually throughout its entire length to the vertebral column; this is especially true of the moles.

11. *Bones of hind limb not so strongly developed as those of fore limb.*— Besides pushing the body forward the hind limbs

are principally used for throwing back the loose earth. Although not acquiring the excessive development of the fore limbs, the femur usually has its trochanters well developed. In Erinaceus it has a strong ridge below the third trochanter. Greater strength is given by the partial anchylosis of the tibia and fibula; in Chrysochloris they are welded at the lower end. Strength is effected in the pes by the great development of the calcaneum, which plays a prominent part in pushing the animal forward. In Talpa the pes has a large sesamoid bone at the side of the tibia corresponding to the os falciforme of the manus, but otherwise it exhibits none of the great modifications of the manus.

C. Physiological Modifications.

1. *Hibernation.*— In the temperate zones where the ground is frozen during a portion of each year, fossorial mammals would have difficulty in getting food. Especially is this the case with those semi-fossorial forms such as the woodchuck which live on soft succulent herbage. Such forms are thus compelled to spend the winter in a long sleep (*e. g.* woodchucks, gophers, hamsters, etc.).

Partial List of Fossorial and Semi-fossorial Mammals.

Monotremata: Ornithorhynchus, Echidna; Marsupialia: Phascolomys, Dasyurus, kangaroo rat, *Bettongia leseuiri*, pig-footed bandicoot (*Chœropus castanotis*), marsupial mole (*Notoryctes typhlops*); Edentata: Dasypodidæ, Orycteropus; Insectivora: Talpa, Condylura, Scalops, water shrew (*Crossopus fodiens*), desman (Myogale), Erinaceus, Oryzoryctes, Chrysochloris; Rodentia: Lepus, Spermophilus, Cynomys, Arctomys, Geomyidæ, Spalacidæ, Rhizomys, Octodontidæ, Cœlogenys, Viscacha (*Lagostomus trichodactylus*), Bathyergidæ, Heterocephalus; Carnivora: Lutra, ratel (Mellivora), Javanese skunk (Mydaus), American badger (Taxidea).

The anatomical conditions prerequisite to progressive modification along fossorial lines evidently include the following: reten-

tion of the primitive characters of small size, generalized (*i. e.* short, more or less plantigrade, pentadactyl) limbs with moderately sized claws and normal relations of the radius and ulna, clavicle and muscles used in digging unreduced, face pointed elongate, dentition adapted to food found in the earth. Hence it is natural that the majority of fossorial forms should have sprung from primitive and defenceless rodents, insectivores and edentates and that the carnivores (especially those with specialized sectorial dentition) the ungulates (mostly herbivorous, and cursorial), the primates (typically light limbed, light clawed, short faced), have as a rule failed either to find protection from foes or abundant food by turning into the barred road of fossorial modification.

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ON THE STRUCTURE OF THE PTERASPIDÆ AND CEPHALASPIDÆ.

W. PATTEN.

I. THE fact which first suggested to me the possibility of a genetic relationship between the Vertebrata and Arthropoda was the similarity in structure and development between the median eyes of arthropods and the pineal eyes of vertebrates.

To test this idea a careful study of the brain, sense organs, cranial nerves, nephridia and skeletogenous structures was made, the results of which showed so clearly a fundamental similarity between the structure and the arrangement of these parts in the cephalothorax of certain arthropods and in the head of vertebrates, as to justify the conclusion that the vertebrates were derived from fully developed arthropod types, and that the solution of the various problems in the morphology of the vertebrate head must be sought for in the evolution of the arthropod cephalothorax.

For the advocate of the annelid theory of the origin of vertebrates, or of any other theory that assumes the vertebrates to be derived from soft bodied ancestors, an appeal to paleontology in support of anatomical or embryological evidence is well nigh hopeless. But for those who support the arthropod theory, such an appeal is imperative because paleontology is not likely to remain forever silent when both extremes of the series of hypothetical annectant types could be preserved as fossils.

The fossil forms that at first sight seemed most completely to bridge the gap between their respective types are the trilobites and Merostommata, representing the arthropods, and the ostracoderms representing the vertebrates. It seemed probable that a study of their remains, especially those of the ostracoderms, whose structure presents so many interesting problems, might furnish evidence for, or against, the supposed genetic relationship between these two groups. Moreover the fact that these ani-

mals are among the oldest representatives of their respective types known, that they were contemporaneous and lived under very similar conditions, and that they presented many obvious external resemblances in form and mode of life, clearly invited a more detailed comparison between them.

The evidence thus far obtained, justifies the belief that paleontology will add its evidence to that of anatomy and embryology in favor of the origin of vertebrates from arachnids.

From the following historical review it will be seen that while it is now generally assumed that the ostracoderms have pronounced affinities with the vertebrates, there is the greatest diversity of opinion among leading authorities as to whether certain organs characteristic of the true vertebrates are present in the ostracoderms or not, and there is also the greatest difference of opinion in the interpretation of those structures which are actually known to occur there. In many cases the despairing admission is made, that if certain openings, or structures, are not this, that, or the other, what can they be? This is not due entirely to the imperfect preservation of the remains, because in some cases they are beautifully preserved.

At the very outset, the obvious differences between the ostracoderms and true vertebrates, and the resemblance between them and the arthropods, was a subject for repeated comment. In fact the resemblance was so striking that it led many of the best earlier observers to describe certain merostomatous arthropods as fishes and various ostracoderms as arthropods. More recent authors while admitting that there is a superficial resemblance between these two great groups, explain this resemblance as one due merely to mimicry or parallelism, and not to a genetic relationship. Some authors even deny that the peculiar structure of the ostracoderms is an indication of their primitive character, but regard them as either highly specialized, or as degenerate offshoots from the class of typical fishes.

At first the discussion centered round the question whether certain genera of the ostracoderms, especially Cyathaspis and Pteraspis were arthropods or vertebrates. But whether or no these genera, and consequently the whole group of the ostraco-

derms, were annectant types uniting the true fishes with the arthropods, and possessing some of the characters of both classes, so far as I know, was not discussed by any writer till I raised the question in 1889, in my first paper "On the Origin of Vertebrates."

Huxley and Lankester answered the first question with great emphasis in favor of the vertebrates, basing their conclusions primarily on the microscopic structure of the head shields, the presence of fish-like scales in Pteraspis, and of a caudal fin in Cephalaspis. Their authoritative opinion settled the question for the time being, and soon afterwards, the almost universal belief in the derivation of vertebrates from soft bodied annelid ancestors that would leave little or no trace behind, and the widespread conviction that the growing science of embryology was to be the final court of appeal in all broad phylogenetic problems, turned the attention of morphologists away from the paleontological aspect of the problem.

The development of new lines of zoölogical research and the failure of embryology to realize the over confident expectations of its disciples, as well as the frequent and flagrant abuses of embryological data, have produced within the last decade a spirit of impatience, or of indifference, towards phylogenetic speculations in general and a reaction set in, not only against the annelid theory of the origin of vertebrates, but against all theories that attempt to bridge this, the widest gap in the whole organic kingdom, by a purely speculative use of embryological data.

The association of such names as Hugh Miller, Louis Agassiz, Huxley and Lankester with the early history of Pteraspis and the Cephalaspidæ adds greatly to the interest that has long centered in this group.

In *Siluria*, (London 1854, p. 252), Sir Roderick I. Murchison speaking of *Cephalaspis agassizii* says: "This fish with its large buckler-shaped head and its thin body, jointed somewhat like a lobster, is perhaps the most remarkable example of a fish of apparently so intermediate a character, that the detached portions of its head when first found were supposed to belong to Crustacea."

In a foot note Murchison adds: "Mr. Miller has requested his readers to compare the head of *Asaphus* (now *Phacops*) *caudatus*, a well-known Silurian trilobite, with that of *C. lyellii*, to illustrate how the two orders of Crustaceans and Fishes **seem** here to meet,—in the view of persons who have not mastered the subject."

Eichwald says ('54, p. 105): "It is very remarkable that this colossal crab (Pterygotus) formerly regarded by L. Agassiz as a fish .... occurs in the dolomitic chalk of Rootziküll in Oesel, together with another genus, Thyestes, standing between Crabs and Fishes and resembling Bunodes and Cephalaspis."

Hugh Miller, the discoverer of Pterichthys, says (*Old Red Sandstone*, p. 50), in comparing a trilobite with Cephalaspis "The fish and the Crustacean are wonderfully alike." .... "They exhibit the points, ... at which the plated fish is linked to the shelled Crustacean."

Sir Roderick Murchison, when first shown specimens of Pterichthys wrote regarding them that, "if not fishes, they more clearly approach to crustaceans than to any other class." Again, "They (Cephalaspis and Pterichthys) form the connecting links between crustaceans and fishes." Agassiz was at first in doubt as to whether Pterichthys was a fish or a crustacean.

The following quotation illustrates the attitude of modern paleontologists toward the ostracoderms. A. S. Woodward, whose opinion on this subject is entitled to the greatest respect, in his recent text-book of Paleontology ('98, p. 5) states that "Nearly all the genera (of the Ostracodermi) mimic in a curious manner the contemporaneous Eurypterids"; and on p. 24 of the Introduction, that "The oldest Ostracoderms .... sometimes claimed as the immediate allies of the crustacean or arachnid Merostomata of the same period, are fundamentally different from the latter in every character which admits of detailed comparison; they are to be regarded merely as an interesting example of mimetic resemblance between organisms of two different grades adapted to live in the same way and under precisely similar conditions."

Surely, no one knows either the precise conditions, under which these forms lived, or the "way" they lived. It would cer-

tainly be a very unusual thing if all the ostracoderms mimicked animals so different in grade of organization according to Woodward's view, as the Merostommata are. As a matter of fact, there is no more reason for assuming that the ostracoderms mimicked the Merostommata, than that the Merostommata mimicked the ostracoderms, and there would have been no obvious advantage to any of them on either supposition.

Moreover the features in which the ostracoderms mimicked the eurypterids are characteristic of a very extensive class and are the very characters which are important in differentiating the ostracoderms from the true fishes, such as, for example, the small pointed body, large shield-shaped head with its peculiar cornua, cephalic appendages, shell covered orbits, unusual character of the parts surrounding the mouth, and the minute structure of the nearly continuous dermal armor. It is the combination of all these characters that makes the resemblance between the ostracoderms and Merostommata difficult to understand on any other assumption than that of genetic relationship.

Clearly it is not convincing, or a final solution of the problem, to say that these extensive resemblances between two great classes of animals are due solely to either mimicry or parallelism.

II. The Pteraspidæ. Going back again to the older writers, we shall see that much of their discussion having any bearing on the position of the ostracoderms was on the structure and relations of the Pteraspidæ. But the fact that these animals were the first fish-like animals to appear on the earth's surface, and that they were found in some of the oldest fossiliferous rocks known, did not influence their views as to the nature of these forms so much as one might have supposed. Although certain parts of Pteraspis and Cyathaspis were at one time thought to be the bones of a cuttle fish, or the shields of trilobite-like crustaceans, a more careful study of their microscopic structure, and a comparison with related forms, showed that they belonged to a group of animals with unquestionable vertebrate affinities. This fact seems to have shut off all further consideration of their phylogenetic signification, for as soon as their vertebrate affinities were once established they were pigeon-holed

among the true fishes, and their existence practically ignored. Although the pteraspids are now generally placed among the true fishes, their head shields do not present a single recognizable vertebrate character. The various surface markings have been supposed to indicate the presence of median or lateral eyes, olfactory, or auditory, organs, or gill openings, or the impressions of gill pouches,— not because they show any particular resemblance to corresponding organs in true vertebrates, but because, as has been frequently said, there is nothing else with which they can be compared. There are no traces in these remains, which in general are fairly well preserved, of upper and lower jaws, fins, notochord, or vertebral column.

The genus Pteraspis was first proposed by Rudolph Kner in 1847 to include the forms described in 1835 by Agassiz as *Cephalaspis lewisii*, and *C. lloydii*. Their appearance was so unlike the ordinary fish remains that for a long time Kner did not suspect that they had been already described by Agassiz in his *Poissons Fossils*.

From a study of their minute structure Kner believed them to be the internal shells of cephalopods allied to Sepia.

In 1856, F. Roemer described a form closely related to *C. lloydii* as Palæoteuthis, and referred it to the Sepiidæ, but suggested that the forms described by Kner were crustaceans related to Dithyrocaris or Pterygotus.

In 1864, Lankester divided the Pteraspidæ into the three genera, Pteraspis, Cyathaspis and Scaphaspis. But in 1872, Kunth described a shield of Cyathaspis, below which he found one belonging to Lankester's genus Scaphaspis, and he rightly concluded that the two shields belonged to the same animal. He maintained that the lower shield bore the same relation to the upper one that the tail plate of a rolled up trilobite does to its head shield, and that between the two were a number of pieces comparable with the segmental trunk plates of a trilobite. Other plates were present which Kunth regarded as locomotor organs, or foot-jaws. From the above facts Kunth concluded that these remains were not those of a fish but of an arthropod. In referring to Huxley's statement that there is no molluscan or crustacean structure with which such remains could be for a moment

confounded, and to Kner's belief that Scaphaspis was the shell of *Sepia officinalis*, Kunth adds "so schienen mir diese Ansichten in verein mit unserem vorliegenden Stücks mir zu beweisen dass wir es mit einer Crustacean Abtheilung von ganz eigenthümlicher Schalstructur zu thun haben. Denn jedenfalls giebt es weder einen Fisch noch eine Sepien Schulpe, die eine ähnliche Structur wie die Schilder zeigte; wohl aber ist die Organization des ganzen Stückes beweisend fur Crustaceen Character" (p. 6).

Both Schmidt ('73, p. 33c) and von Alth (p. 47) agree with Kunth that Scaphaspis is the ventral shield of Pteraspis, but they deny that any of the remains described as Pteraspis, Cyathaspis or Scaphaspis are crustaceans, although no valid reasons are given for doing so.

Huxley ('58, p. 277) in reply to Agassiz, who had remarked on the singular resemblance between the shell of *C. lloydii* and that of crustaceans, and to Roemer's and Kunth's opinion that Pteraspis was a crustacean, seems to have closed the discussion for the time with his oft quoted statement that "No one can, I think, hesitate in placing Pteraspis among Fishes. So far from its structure having 'no parallel among fishes,' it has absolutely no parallel in any other division of the animal kingdom. I have never seen any molluscan or crustacean structure with which it could be for a moment confounded."

Roemer accepts these statements apparently because they came from Huxley, although he does not make an unconditional surrender of his opinion, for he says "Allerdings manche Analogie der aüsseren Form mit Crustacean-Formen dar bieten wurde."

In 1855, R. W. Banks in his paper on the Downton Sandstones, after commenting on the association in these beds of *Lingula cornea*, Pterygotus and Pteraspis (Cyathaspis), made the following observation, p. 98, "On the under side of the sharp projections before referred to (on either side of the rounded snout) are protuberances which seem to be projecting horny eyes similar to those of Crustaceans."

He remarks further on, that doubtful as it is whether the buckler-like fossil remains above referred to belong to fishes or to crustaceans, it is certain that they are closely allied to *Cepha-*

Iaspis lloydii and *C. lewisii*. In a final note, it is announced that Professor Huxley is now minutely examining their structure to determine their true relationship either to the crustaceans or to the fishes. When Huxley's paper appeared, although he gave a very good description of the minute structure of the shell of these animals and concluded that they are not crustaceans, he entirely ignored the existence of the eye tubercles, although their presence afforded very weighty evidence against his conclusion.

Lankester ('68, p. 26) admitted the presence in Cyathaspis of tubercles corresponding with similar tubercles in Pteraspis, which are "produced by the supposed orbits"; but how a vertebrate eye, or an "orbit," could be preserved as a beautifully rounded protuberance when all the other soft parts are completely destroyed, is not discussed.

Lankester however, ('73, p. 241), still maintained the validity of his genera Scaphaspis and, in another article ('73, p. 190) makes the following statement: "It is to me a source of twofold regret that Dr. Kunth has perished in the Franco-Prussian war, for not only have we thus lost a chance of obtaining additional knowledge of the Berlin Cyathaspis, but I shall be unable to obtain from him the admission that his conclusion is not in accordance with the facts." Lankester ('91) finally admits that von Allth's discovery shows Scaphaspis to be the ventral shield of Pteraspis, and thus we may assume that his "twofold regret" for Kunth's untimely death was in a measure mitigated.

Lankester attaches much importance to the presence of scales on the anterior trunk region of Pteraspis, for these scale-like structures are regarded as conclusive proof that the Pteraspidæ belong to the vertebrates. As Lankester says ('68, p. 18) "All that is known as regards the scales of these Fishes is from a single specimen found in the Cornstones of Herefordshire." This specimen, he says elsewhere ('73, p. 191) "Shows seven rows of rhomboidal scales attached (not merely adjacent to) to a portion of the head shield of Pteraspis. That these are true scales, or lozenges of sculptured calcareous matter is absolutely certain. It is also absolutely certain that the shield is pteraspidian and that the scales and shield belong to the same individ-

ual organism. The scales are fish-like. I know no Arthropod, nor any other organism except a fish which possesses any structure even remotely representing them." "The shields of the Chitonidæ and Cerripedæ are the only animal structures, except the scales of a ganoid fish (with which they agree exactly) which they could even vaguely suggest." "The form of this shield, and its details as to apertures, processes, etc., agrees with the view that it belongs to a fish most fully. It has not the remotest suggestion of Crustacean affinities about it."

After commenting on the fact that the fossil in question was marked with long parallel striæ, and that the middle layer contained the polygonal cavities he adds ('64, p. 195), "This structure, which has no parallel among fishes, or, indeed, any group of the animal kingdom, leaves no possibility of a doubt that the specimen is a fragment of Pteraspis." .... Lankester further maintains ('68, p. 4) that by the discovery of these scales "the piscine nature of these fossils was definitely set at rest."

These positive statements are somewhat contradictory and would now be hardly warranted by the facts of the case. The crustacean character of the shields has been repeatedly commented on by competent observers. In his own monograph (p. 61) he has described a fragment, possibly connected with Cephalaspis which he names *Kallostrakon podura* (Tolypelepis?) "on account of the resemblance to the well-known microscopic markings of the scales of the insect Podura."

It is not true that there are no arthropods with structures even remotely resembling these scales, because in Pterygotus the entire body is covered with an ornamentation which bears an astonishing resemblance to fish scales, so much so as to deceive such a keen observer of fishes as Louis Agassiz. Moreover in many trilobites and in the Ceratiocarina, Clarke, the surface of the shell is ornamented with ridges and grooves not unlike those of Pteraspis in external appearance.

Lankester probably would not have made these statements had he kept Pterygotus in mind, or had he been acquainted with the minute structure of the shield of Limulus.

Moreover all recent students of the shell of Pteraspis are agreed that it is *not* "exactly" like that of a ganoid fish, in fact its microscopic structure is altogether of a different character.

But after all, the presence or absence of these scales in Pteraspis has little weight, it seems to me, in answering the real question at issue, namely whether Pteraspis in addition to its vertebrate affinities has not also a genetic relationship with the arthropods.

Lankester, Woodward, Traquair, Rohon and others agree in denying the existence of arthropod characters to the pteraspids, apparently because of the abundant evidence now available that Pteraspis is related to Cephalaspis whose ichthyic affinities have rarely been questioned, rather than because the arthropod features of Pteraspis have been dispassionately considered and found wanting.

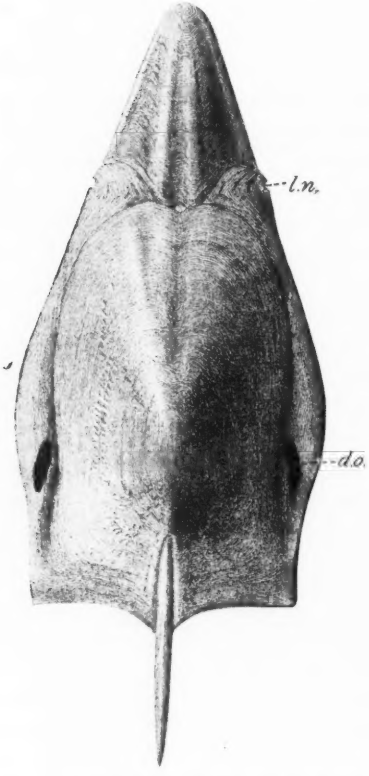


FIG. 1.—Cephalic buckler of Pteraspis, dorsal view, after Lankester. The shape of the lateral openings, *d. o.* has been slightly modified; *l. n.* the supposed lateral eye openings, possibly, the points for attachment of appendages.

But within recent years there seems to be a growing tendency to doubt the affinity between Pteraspis and Cephalaspis. Reis protests against their union, and apparently Traquair is in doubt, treating them together largely as a matter of convenience. Lankester in his earlier monograph states that "The Heterostraci are associated at present with the Osteostraci because they are found in the same beds, because they have like

Cephalaspis a large head shield, and because there is nothing else with which to associate them." More recently he has said ('97) "There is absolutely no reason for regarding Cephalaspis as allied to Pteraspis, beyond that the two genera occur in the same rocks, and still less for concluding that either has any

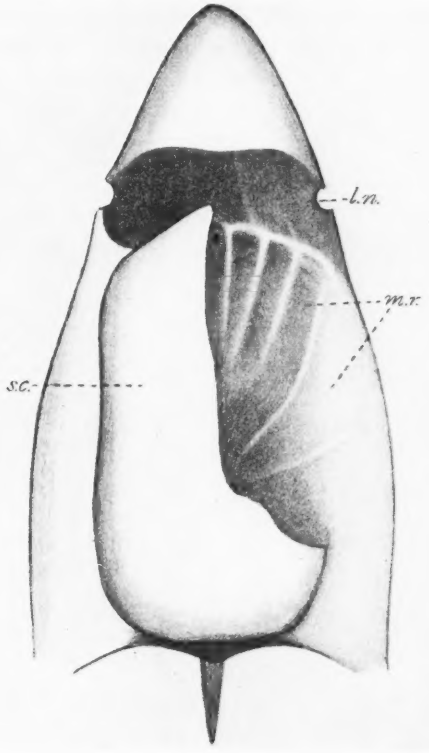


FIG. 2.—Cephalic buckler of Pteraspis, ventral view, showing the small oral region, probably filled with several pairs of plates. The large ventral plate, *s. c.* is supposed to be cut away on one side showing the median eye pit and the paired muscle markings of the inner surface of the dorsal shield.

connection with Pterichthys." Zittel says, Vol. III, p. 147, "Mir scheinen die Beziehungen der Pteraspiden und Cephalaspiden nach Form und Structur so entfernt dass beide besser als

besondere Ordnungen betrachtet werden." He remarks further on that while the Cephalaspidæ certainly appear to be ganoids, the position of the Pteraspidæ is very doubtful.

It seems to me that there can no longer be any doubt on these points, since the Pteraspidæ and Trematasпidæ are pretty closely united with the Asterolepidæ by the similarity of their oar-like appendages, and with the Cephalaspidæ, by the similarity of the median and lateral openings in Trematasпis, Thyestes and Cephalaspis.

At present, of the genus Pteraspis, only a part of the cephalic armor and a few scale-like structures belonging to the anterior part of the trunk, are known. The head, Figs. 1 and 2, is arrow shaped and covered by a dorsal and ventral shield, the latter, the so-called Scaphaspis, consisting of a single ovate or oblong piece, varying in different species from 1½ to 3½ in. in length.

The lateral edges of the ventral shield probably fitted closely to the lateral edges of the dorsal one, leaving under the rostrum a comparatively small opening in which the various mouth parts were situated.

The boat-shaped dorsal shield is composed of seven portions, marked off on the outer surface of the shield by furrows, and on the inner surface by ridges. In young specimens, the rostrum and the central disc may be found separately. Each piece has its surface ornamentation of ridges and furrows arranged in concentric lines parallel with its margins. This fact, together with other considerations, led Lankester to believe that each piece ossified from a separate centre and that their complete anchylosis occurred only in the adult.

Muscle Markings.—In 1872, A. Kunth described in *Cyathaspis integer* a series of six "flache Höcher," situated on the under surface of the dorsal shield, which he regarded as indications of segmentation, Fig. 4. Lankester, ('73), describes similar impressions on the shield of *Cyathaspis banksii* and believes that in both cases they indicate the position of a series of branchial chambers.

In Pteraspis also, Lankaster has described five narrow ridges, with four broad shallow depressions between them, which radiate

from the centre of the inner surface of the dorsal shield, Fig. 2, *m. r.* They are perhaps best marked in *Pteraspis crouchii* and *P. rostratus*.

These markings on the dorsal shield of the Pteraspidæ are, I believe, best explained as indications of the original segmentation of the head, produced in part by the attachment of strong segmental muscles extending vertically from the inner surface of the dorsal shield, either to a cartilaginous cranium, or to a series of gill-like or jaw-like segmental appendages on the ventral side. They suggest the markings produced in this manner on the dorsal surface of the cephalothorax of Limulus, or the lobulations on the dorsal shield of a trilobite head.[1]

Eyes.— There is a conspicuous pit on the inner surface of the shield, appearing on the outer surface as a small tubercle, which marks the position of the median eyes.

Lankester ('70) shows in his Fig. 6, Pl. IV, three tubercles near the median anterior part of the head of Cyathaspis, and the same tubercles were figured by A. Kunth in 1872. In both figures, the resemblance of the shields to the cephalothorax of an arthropod is intensified by the shape and arrangement of these three ocelli-like tubercles (Fig. 4).

The location of the lateral eyes of Pteraspis is supposed to be indicated by two smooth tubercles, or in some cases by circular openings, near the anterior margin of the shield, *l. n.* It is hard to understand how the usual type of vertebrate eye could be preserved in the form of these tubercles. If they are lateral eye tubercles, they, like the compound eyes of arthropods, must have been enclosed by a firm dome-like covering, continuous with the outer layers of the shell. I have never seen any specimen of Pteraspis in which these so-called lateral eye notches were actually covered by an extension of the outer shell layer, although such a covering is found over the large median eyes of Cephalaspis and Trematapis. It is possible that there are two pairs of such notches, or openings, in Pteraspis, Cyathaspis and Tolypelepis, one serving for the lateral eyes and the other for the attachment of swimming appendages similar to those of Trematapis.

[1] Rohon has described a somewhat similar segmentation of the head in Thyestes.

The projections sometimes seen in the so-called orbital notches of Pteraspis, appear to be the remnants of appendages.

Dorso lateral openings.— In Pteraspis a large oval opening on each side of the dorsal shield leads into a wide canal that runs diagonally forward and downward into the interior of the head (Figs. 1 and 3, *d. o.*). Lankester ('68, p. 17) says, "It is very difficult to find any explanation of these open excavated structures unless they be spiracles."

Although the margins of these openings are not well enough preserved to show such important details as are seen in Trematapis, their shape and position indicate that they may be homologous with the lateral openings in the dorsal shield of Cephalaspis, Thyestis and Trematapis. Like the openings in the shields of these three genera, they were probably covered by an extension of the outer shell layer, possibly by loosely fitting polygonal plates. This may be the reason why Claypole, (p. 566), found no trace of such openings in Palæaspis.

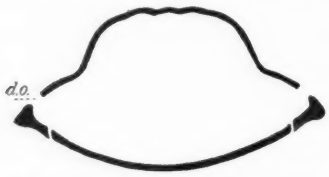


FIG. 3.—Cross section through the posterior portion of the cephalic buckler of Pteraspis. The section of the dorsal shield with its lateral openings is from an actual section. The ventral shield is restored.

Sections of two different specimens (Fig. 3) show that there is no extension of the inner layers of the shell over the opening, like that seen in Trematapis and Cephalaspis.

If this interpretation of the lateral openings in Pteraspis is accepted, there is no reason for supposing that they have anything to do with the gills, and the argument that Pteraspis is a fish because it has spiracles, or gill openings, is eliminated.

Appendages.— In *Palæaspis americana*, Claypole ('92, p. 554), finds indications of appendages consisting of small objects resembling spines "margined with what appeared to be a flat fringe around their smaller and pointed ends; .... the central spine-like portion was covered with a layer of the same tissue as that of which the shield was composed." He then adds that the resemblance of the structure to a crossopterygian fin was obvious. "Two forms of fins appear to prevail, the one broad and

the other narrow, indicating that more than one pair belonged to the same individual."

These facts are of great significance in view of Lindström's discovery of the appendages in Cyathaspis, (Fig. 4) and of my own discovery of appendages in Tremataspis. Dean ('95, p. 71) maintains that the structures in question do not have the significance claimed for them by Claypole, and that they do not even belong to Palæaspis but to some elasmobranch. But Claypole's observations seem to have been made with great care, and in view of the importance that must be attached to them, if confirmed, they deserve more careful consideration than they have heretofore received.

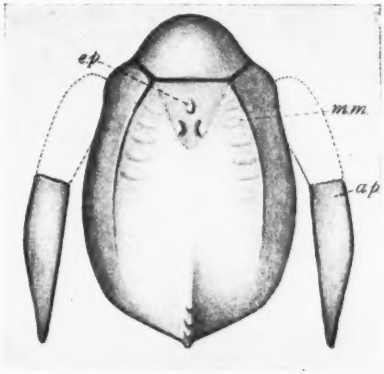
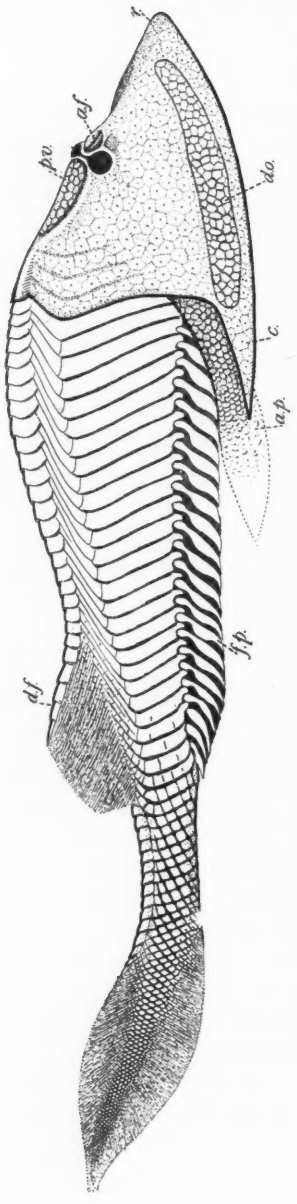


FIG. 4.— Restoration of the head shield of Cyathaspis, showing the oar-like appendages, *ap.* the three median eye pits, *ep.* and the paired muscle markings, *m. m.* sometimes regarded as the impressions of gill pouches. The eye pits and muscle markings are best seen in casts of the inner surface.

III. THE CEPHALASPIDÆ are found in the upper Silurian and in the Devonian formations, and range in size from a few inches to possibly two feet or more in length.

Shape of Head.— In Cephalaspis, (Figs. 5 and 6), the typical genus of the family, the head was completely enclosed in a continuous cephalic buckler or shield, which seen from above is elipsoidal in outline, either rounded or pointed in front and truncated behind. The lateral angles of the posterior margin extend backwards to form the cornua, while the median posterior portion forms a broad crest often armed with a prominent median spine.

Cross sections (Fig. 8 *B*) show that the head is thin and



spoon-shaped, with its concave surface facing downwards. It rests on a flat, thick-walled rim which gradually widens posteriorly till it forms the under side of the broad triangular cornua. The ventral wall of the shield is thin, and is pressed closely against the dorsal wall. Toward the middle line it is gradually reduced to a flexible membrane which terminates abruptly, leaving a large median opening in which the soft parts of the head were situated.

Eyes.— Near the middle of the dorsal surface are the oval openings for the eyes. Cross sections of the orbits, and fragmentary casts of their outer surface, show that the eyes were nearly spherical, and that they projected dome-like above the surface of the head. They were covered by a thin coating of hard material continuous with the outer layer of the shield. The floor of the orbits is very concave and consists of a basket work of bony trabeculæ formed by an extension of the inner shell layer.

FIG. 5.— Restoration of Cephalaspis, seen from the side; no attempt has been made to indicate specific differences; *a. p.* cephalic appendages, so-called "opercular flaps," *c*, cornua; *d. o.* marginal organs; *r.* rostrum; *a. f* ant-orbital fossæ with median perforation; *e.* eyes; *p. v.* post-orbital valley; *d. f.* dorsal fin; *f. p.* fringing processes.

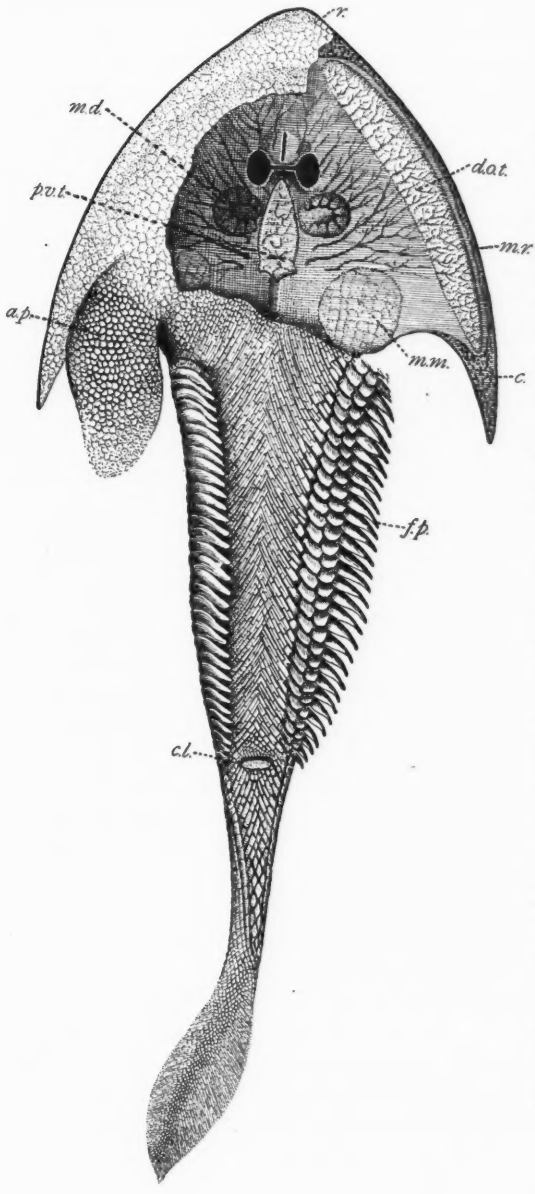


FIG. 6.—Restoration of Cephalaspis, seen from below. A part of the ventral wall of the head is shown on the left, the rest is removed, showing inner surface of the roof of the shield; *m. r.* net work of osseous trabeculæ supporting the margins of the shield; *d. a. t.* mass of bony tissue forming the floor to the lateral openings; *p. v. t.* same kind of tissue below the post-orbital valley; *m. m.* large muscle scar; *f. p.* fringing processes, extended on right, and folded on to abdomen on left; *cl.* cloacal opening. Other letters as in Fig. 5.

The eyes, therefore, of Cephalaspis, like those of Trematapis and Bothriolepis were imbedded between two layers of the dermal armor, and in this respect agree with the condition which prevails in both the median and the lateral eyes of Limulus (Fig. 8 *A*).

Two depressions lie just in front of the orbits (the so-called ant-orbital fossæ (*a. f.*). They are separated by a median crest,

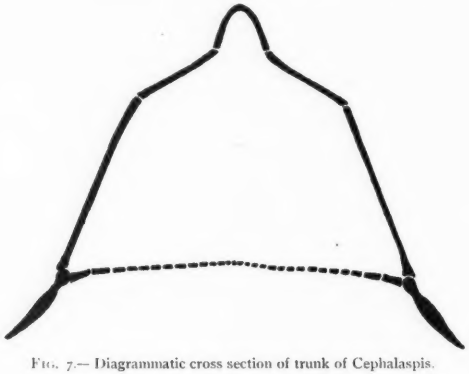


FIG. 7.— Diagrammatic cross section of trunk of Cephalaspis.

the summit of which is perforated by a narrow slit which leads into the interior of the head.

On the inner surface of the shield, near the lateral margins, are two very large oblong thickenings composed of a net-work of osseous trabeculæ (Pl. I, Figs. 2, 3 and 4, and text figs., 5 and 6, *d. o.*). Another prominent mass of the same tissue lies in the median line, just behind the orbits and just beneath the post-orbital valley (*p. v.*).

These lateral thickenings have been obscurely indicated in some of Lankester's figures, but I can find no reference to them in the text. They are probably the "pair of great rounded lobes meeting in the middle line" mentioned by Woodward (p. 179, Part II), and the "pouch-like sensory organs" of Dean ('95, p. 67).

In the specimens here figured the lateral lobes do not meet in the median line and I have not seen any specimens in which they do. When the outer surface of the shield is preserved, it

shows a well defined opening corresponding in position and outline with the mass of trabeculæ below. In some specimens, the opening is covered by a special group of loose, irregular polygonal plates, well shown in Pl. I. Fig. 3.

The mass of trabeculæ below the post-orbital valley is conspicuous and is often very sharply outlined (Pl. I. Fig. 2). It is oblong, pointed in front, and broad and somewhat angular behind.

The post-orbital valley when seen from above, in well preserved specimens, presents a clearly defined oblong opening, similar in shape to the underlying mass of trabeculæ, and filled with polygonal plates similar to those of the marginal openings.

In Thyestis, Fig. 9, I have found marginal and post-orbital

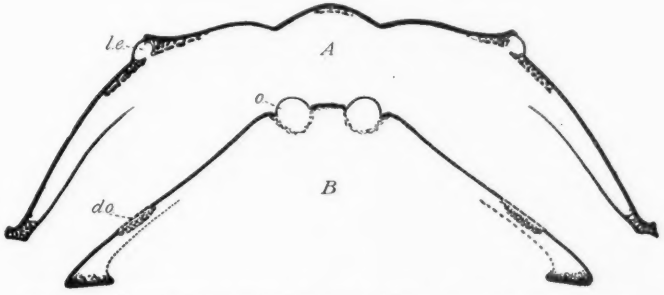


FIG. 8.—A. — Cross section of the cephalothorax of Limulus, showing arrangement of the bony trabeculæ in the median line, below lateral eyes and on the margins of the shield. The section is too far back to show the trabeculæ below the median eyes. B.— Cross section through the head of Cephalaspis, showing orbits, lateral organs, and part of the ventral shield.

openings similar to those of Cephalaspis, but smaller and more like those of Trematapis. The covering polygonal plates, however, are absent.

There can be no doubt that the marginal and post-orbital openings of Cephalaspis and Thyestis, and perhaps the marginal openings of Pteraspis, are the same as those so well shown in Trematapis, and that in all these genera some important organ of a sensory nature was lodged between the two layers of the shield at these points. I have shown that the arrangement of the marginal openings in Trematapis is very suggestive of that of the lateral eyes and dorsal organs of Limulus (:01, p. 7).

The marginal cells of Eukeraspis Lank., seem to be a special development of bony trabeculæ similar to those below the lateral openings, but more loosely arranged. They serve to unite the dorsal and ventral laminæ, and to give additional strength to the rim of the shield.

I have already pointed out (:01), that in Limulus there is a system of supporting bony trabeculæ similar in structure and arrangement to those in Cephalaspis. In Limulus, as in Cepha-

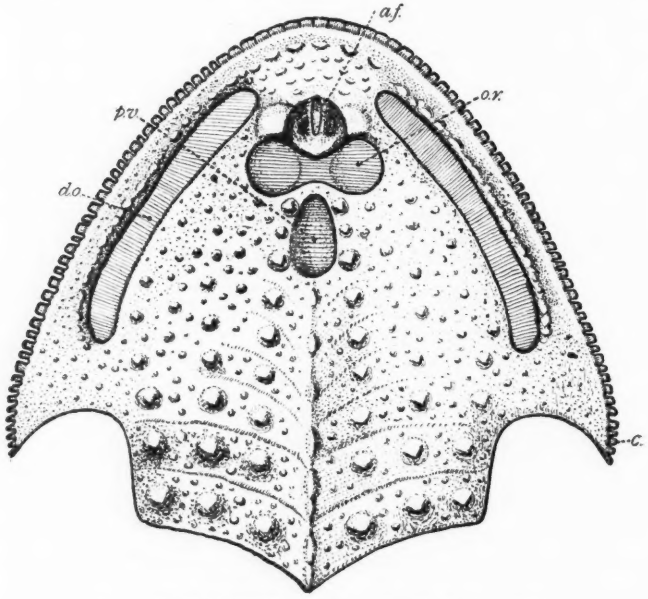


FIG. 9.— Head shield of Thyestes, × 4. Letters as in Figs. 5 and 6.

laspis, the principal masses of the trabeculæ lie along the margins of the shield, in the cornua, and beneath the median and lateral eyes.

Trunk Scales and Fins.— The dorsal surface of the trunk is covered with a single row of saddle-shaped, overlapping scales, sometimes fused into larger groups. The ridge scales extend on to, and support, the anterior margin of the dorsal fin, which appears to be merely an expansion of the dorsal ridge.

The dorsal fin must have been nearly immovable, as it is sheathed with parallel rows of oblong scales which diminish in size toward the free margin. The tail lobe is covered by similar scales. It was diphycercle, not, as is usually stated, heterocercle. In some cases I have seen indications that it terminated in a long, banner-like filament.

The flanks are covered by two principal rows of scales, the dorso-lateral one consisting of plates placed at a sharp angle with the dorsal crest, and in some cases twice as numerous as the crest scales (Pl. II, Fig. 7). The posterior edge of each scale overlaps the anterior edge of the next following one.

The lateral trunk plates are much larger, and stand nearly vertical. There is a semicircular incision on the posterior angle of the ventral end of each scale, into which fits the head of the fringing processes. The scales begin to break up into irregular polygonal plates about opposite the cloaca (Pl. II. Fig. 6, and text Fig. 5).

The ventral surface of *Cephalaspis murchisoni* is flat and triangular in contour. It widens out towards the ventral surface of the head, and narrows toward a point a little distance behind the cloaca. Its lateral boundaries are sharply defined by the projecting fringing processes. It is covered with small scales arranged in well defined rows, directed from either side diagonally inwards and forwards (Pl. II, Fig. 5). In *Cephalaspis lyelli*, they are directed backwards.

The outermost ones of the ventral scales appear to be nearly square and in some places (Fig. 6) present a distinct joint for the articulation of the fringing processes. Next to them comes a rather large oblong plate. The remaining scales in each row diminish in width as they approach the median line, where they are sometimes curiously crossed as though formed by imbricating filaments.

Cloaca.— In one beautiful, heretofore undescribed specimen in the British Museum (P. 8804 ?) about two thirds of the distance from the anterior end of the trunk, there is a well defined transverse slit that no doubt represents the cloaca (Pl. II, Fig. 5). Its posterior lip is smooth and rounded, the anterior one is more sharply defined, and forms the basal line of a triangular area covered with minute rhomboidal scales.

Back of the cloaca, the scales are arranged in obscure V-shaped rows, gradually breaking up into the squarish plates seen on the sides and ventral surface of the root of the tail.

Mandibles.— In my paper before the Fifth International Congress at Berlin, I referred to the presence of certain problematical structures in the head of Cephalaspis. I stated that my attention was first called to this subject several years ago by one of Lankester's figures (Pl. X, Fig. 2) which seemed to suggest the possibility of some kind of appendages on the under side of the shield, in the mouth region. Lankester made no reference in the text to the structure in question. On examining this specimen in the Edinburgh Museum of Arts and Sciences (No. 182), two oval bodies were found, lying in about the middle of the under side of the shield, just back of the orbits, and conspicuous on account of their peculiar shape and smooth shining surface.

Each body had a smooth under surface with fluted sides. Their symmetrical form and arrangement shows beyond doubt that they formed an organic part of the head.

The muscles moving these structures at first appeared to be attached to the large, circular, muscle scar on the inner surface of the dorsal shield, between the cornua and the posterior part of the dorsal crest (Fig. 5, *m. m.*) but I am now inclined to believe these marks were made by muscles moving the so-called opercula.

It is extremely probable that similar mouth parts occur in other ostracoderms. In Trematapis, I have shown that the oral plates so completely fill the opening in this region that there is little room for the presence or action of upper and lower jaws of the vertebrate type. The shape and arrangement of these plates indicate that the large anterior pair in Trematapis represent the mandibles which like those of the arthropod type must have moved to and from the median line when in use.

In Bothriolepis, we see even more clearly, as we shall describe in more detail elsewhere, that the so-called mental plates were mandibles of this kind. They are the only pair of plates present that could serve as jaws, and their general contour, the long

muscle ridge on their inner surface and the thickened, inturned median ends, that were probably armed with chitinous, or horny sheaths, show that they acted against one another in the median line, either as cutting, or crushing jaws. Their structure and position show in the clearest manner that the mouth must have been situated *between* these mandible-like plates, not in front of them. The presence of these remarkable structures around the mouth of the ostracoderms shows more clearly perhaps than anything else how wide the gap is between them and the true fishes.

Appendages.— Powrie was the first to call attention to the paddle-shaped lappets, or so-called pectoral appendages of Cephalaspis. They were later described and figured by Lankester and Powrie as "Ellipsoidal expanses with some calcareous matter in their structure which has caused them to be preserved." They are characterized by a kind of reticulate or areolate marking and although they show no trace of fin rays, they were regarded as a remarkable kind of pectoral fin, "efficient in causing currents of water to pass to the branchial organs."

Woodward has more recently examined some well preserved specimens of *C. murchisonii* and makes the following statement in regard to them: (Cat. B. Museum, p. 186). "A novel point of much general interest is elucidated by the middle layer of the shield, which is well preserved in several specimens." "The present specimens prove distinctly that it extends backwards as a pair of postero-lateral 'flaps' beyond the rest of the shield." "The outer layer is broken away, so that direct continuity can be observed between the appendage and the middle layer." "The structures are merely a portion of the shield itself, divested of the outer and inner layers to insure flexibility" (p. 187).

After quoting Lankester's opinion of them, he adds, "Some connection with the gills has thus already been suspected and it now seems most probable that the appendages in question actually correspond to a pair of opercula, and may henceforth be designated as such."

I have studied these appendages in the collections of the

British Museum and those at Edinburgh, but could find no evidence that the folds are formed as extensions of the middle layer of the shield. They appear to me to be covered by the usual shell layers, but broken into small shell-like plates united in such a manner as to allow some flexibility to the whole structure. They are not in my opinion specializations of the posterior lateral margin of the cephalic shield, or of the cornua, but true appendages attached to the under side of the head. The large circular muscle scars seen on the inner surface of the dorsal shield (Fig. 5, *m. m.*) probably served for the attachment of muscles moving these appendages.

I cannot agree with Woodward and Lankester in regarding these structures as opercula, for sections indicate that the sides of the head were very thin, and that the most important cranial organs were near the median line. Hence the so-called opercula, standing so far back, and to one side, and when the animal was at rest lying flat-wise against the bottom, were not in a position to cover the gills, or to produce currents of water through them.

Traquair regards the lappet-like flaps of the Cœlolepidæ as pectoral fins. These "lappets" it seems to me are represented in the Cephalaspidæ, by the cornua. Traquair's position is a difficult one to maintain, in that it compels him to look on the cornua of Drepanaspis as fins "rendered utterly functionless as fins by being enclosed in unyielding bony plates" (p. 846).

The true interpretation is to be obtained, I believe, by reversing this order of events and assuming that the ridged cornua of forms like Cephalaspis, Pteraspis, Drepanaspis, and others, are homologous and the most primitive because they are most like the cornua of their arthropodan ancestors. It is well known that cornua like those of Cephalaspis are present in many trilobites, and that in Limulus the two walls of the cornua are united by bony trabeculæ produced by an elaborate development of the inner shell layers, and suggestive of the reticulated structures filling up the cornua of Cephalaspis.

According to Dean, ('95, p. 69) the large oar-like appendages of Pterichthys are "lateral head angles produced and specialized" for locomotion.

If it is so easy in this instance to create *de novo* highly

specialized appendages like those of Pterichthys, with their necessarily complex arrangement of muscles and nerves, then the elaborate discussions over the origin of the paired appendages of higher vertebrates would seem to be a waste of time. But some such explanation as that offered by Dean is forced on those who regard these animals as true fishes by the difficulty, from their point of view, in explaining the presence of so many different kinds of appendages in a vertebrate head, for it is generally assumed that the appendages of Pterichthys are not homologous with those of Cephalaspis, and that neither one nor the other are homologous with true pectoral fins.[1]

The Fringing Processes. — Lankester showed long ago, in his reconstruction of Cephalaspis, a fringe of peculiar plates along the ventral margins of the trunk, which, although they produced a most unusual appearance, have not attracted the attention they deserve. Whatever their significance may be, there is apparently nothing known in true fishes that is exactly comparable with them.

In one specimen belonging to the Powrie collection in the Edinburgh Museum (No. 163) the body was badly crushed, throwing the plates to one side where they lay flatwise and well separated. On examination with a lens, some of the plates appeared to consist of at least two joints, possibly three, the distal one being the smallest. The surfaces of the plates were covered with coarse spines. The details of this specimen were not brought out by the photographs with sufficient clearness to allow them to be reproduced.

In the beautiful Ledbury specimens of *Cephalaspis murchisoni*, described by Woodward, the fringes are clearly seen in various positions, either from the sides or from below (Pl. I, Figs. 1 and 5.) In most cases they form a series of regularly overlapping, oblong plates, apparently in their normal position on the ventral margin of the trunk. Each plate appears to be three lobed, the segmentation being indicated by the gently rounded outline of each joint, as well as by the transverse lines that separate one

[1] Jaeckel (:02, p. 111) regards the "opercular flaps" of Cephalaspis as homologous with the dermal skeleton of a crossopterygian pectoral fin.

joint from the other. The mode of articulation with the body scales is not shown by any specimens of this species examined.

In the magnificent specimen originally described by Agassiz, (Pl. II, Fig. 6) the animal lies at full length in a natural position. Here the fringing processes are seen edgewise, and have a different shape and appearance from those of *Cephalaspis murchisoni*. They hang freely away from the trunk, in a nearly vertical position, with their distal ends bending backwards in graceful curves. Each process has a rounded head that fits into a cup-like depression on the posterior ventral margin of the large dorso-lateral trunk scales. Below the rounded head, the process is at first quite slender, then somewhat abruptly thickened, and finally reduced to a thin lamella with indistinct boundaries. There are from twenty to thirty pairs, beginning just back of the cephalic shield and gradually decreasing in size from that point toward the tail end. The most posterior ones are reduced to mere spines, or rhomboidal plates, loosely articulated to the lateral trunk scales.

Finally in a small specimen in the Powrie collection at Edinburgh (No. 139), where the whole animal is seen in outline from below, the fringing processes of both sides are shown folded inwards and flattened against the ventral wall of the body (Fig. 10). On the left side of the figure, one can count about twenty processes.

The varying appearance of the processes is due in part to their position and to the way in which they are exposed, and in part to the fact that the plates belonging to different species differ considerably in structure.

In *Cephalaspis murchisoni*, the fringe plates are lobed and overlap one another so that their flattened surfaces are directed diagonally forward and outward. In *Cephalaspis pagei*, they appear to have a similar shape and arrangement, but are armed with coarse projecting spines that give them a decidedly arthropod appearance. In *Cephalaspis lyellii*, the plates lie one directly behind the other without overlapping, while the prominent articulating head, the narrow neck, the posterior swelling and the thin, backwardly directed distal ends give them a unique and characteristic appearance.

FIG. 10.—Small specimen of Cephalaspis seen from below. It shows on the left the fringing plates folded over on to the abdomen.

There can be no doubt that the fringing processes projected freely from the ventral margin, and that they were freely movable forward and backward, and to and from the median line.

The conditions we have described are not less extraordinary than the fact that such conspicuous structures should have remained so long practically unnoticed. Lankester does not discuss their possible signification in his text, but merely introduces them into a very diagrammatic cross section as plates protruding like bilge keels away from the body. Many of the newer specimens of *Cephalaspis murchisoni* in the British Museum, as well as some of the older type specimens, show in the clearest manner that the fringing processes are articulated to the ventral margins of the body and are not artificial folds made by pressing together the margins of the dorsal and ventral walls (Fig. 7).

That the whole group of ostracoderms was provided with a series of fringing plates similar to those of Cephalaspis is very probable, for a series of fringing plates are known to exist in Trematapis, and I have found indications of fringing processes in the trunk of a fine specimen of Pterichthys preserved in the geological collection of McGill University.

Morphology of Vertebrate Appendages.— Organs so widely distributed in a primitive group of animals as the fringing processes are, must have great morphological significance. But while there is little doubt that they are the antecedents of the lateral fold of vertebrates, for no other structures so clearly reproduce in size, position and function the hypothetical folds from which the paired fins are supposed to take their origin, that fact does not help us to determine the morphological significance of the fringing plates themselves.

The fact that the fringing plates are marked with the same surface ornamentation as the trunk scales shows they are not comparable with internal fin rays. On the contrary, their ornamentation, shape, and mode of articulation indicate that they are independent, segmental structures. It is difficult to interpret such structures as anything else than appendages, having the same significance as the rudimentary abdominal appendages of arthropods.

Assuming that to be the case, we may form some idea of their probable mode of development by a comparison with those of Limulus. Miss Hazen and the writer have shown that here each abdominal appendage arises first as a fold of ectoderm, into which grows a muscle bud that soon divides into two principal parts to form the adductor and abductor muscles. Meantime the nerve to the appendage appears and an axial core of cartilage is formed which grows from the basal mesoderm through the middle of the muscle cells, toward the apex of the appendage.

As these processes agree in every essential particular with those known to occur in a segment of the lateral fold of vertebrates, there can be no serious objection, from an embryological standpoint, to the interpretation of the lateral fold as a series of fused abdominal appendages. Assuming then that the lateral fold is formed, phyllogenetically, by the fusion of a series of segmentally arranged, and independently movable structures, such as the fringing processes of the ostracoderms, it is clear that the oar-like cephalic appendages of the ostracoderms cannot be regarded as specializations of either a lateral fold, or of gill arches in the Gegenbaurian sense. On the contrary we must consider the paired cephalic appendages, gill arches and fringing processes as various modifications of one set of serially homologous structures, the pectoral and pelvic fins of modern vertebrates, being a comparatively recent specialization of a partially fused series of such appendages in the trunk region.

I assume, therefore, that the highly specialized condition of the visceral arches and appendicular structures of modern fishes arose through the modification of paired segmental appendages. Even in the more remote ancestors, such as the Phyllopoda, Trilobita, Phyllocarida and Merostommata. These appendages varied greatly in form and function in different animals, and in different regions of the body in the same animal.

In the ostracoderm type, we may assume that certain ones of the anterior cephalo-thoracic appendages were retained as oar-like swimming appendages. Two or three pairs were retained about the mouth followed by several pairs of respiratory appendages of an unknown character.

The trunk appendages were represented by the series of fringing processes.

We may assume that the evolution of the true vertebrates was accompanied by the fusion of the paired mouth parts into unpaired upper and lower jaws, by the further specialization of the gill pouches, the reduction of the free cephalic appendages to such embryonic structures as certain oral papillæ or tentacles, external gills, and the larval balancing organs seen in certain amphibian larvæ, and by the fusion of the abdominal appendages to form the lateral fold from which in turn arose the pectoral and pelvic appendages.

The above interpretation of the origin of paired appendages retains the strong points of both the gill arch, and the lateral fold theories, without the weak points of either. It gives us precisely what Gegenbaur claims has heretofore been lacking in the lateral fold theory, namely: (1) a reason for the existence of the primary fold of ectoderm that initiates the formation of the lateral fold; (2) a reason for the migration into it of segmental detachments of muscle, nerve and cartilage; and (3) a primary function for the lateral fold out of which a set of locomotor organs could be logically developed.

We may explain the presence in the ostracoderms of two or more pairs of cephalic appendages that are not homologous with one another or with the pectoral fins, without being forced to assume that such highly specialized structures are nothing but movable spines or cornua, or flexible flaps, without any known antecedent function or significance. We may agree with Gegenbaur that there is a certain homology between gill arches and specialized portions of the lateral fold, without assuming the extensive migrations of gill arches demanded by his theory, and we may agree with Dohrn that structures homologous with gills, or associated with them, extended far back into the trunk region without assuming that true gill arches and visceral clefts were present there.

IV. MODE OF LIFE OF THE OSTRACODERMS. — We may form some idea of the mode of life of the Ostracodermata by considering the shape of the body and its armor, the nature of the appendages, and the position of the eyes and mouth.

That the Cephalaspidæ were sluggish animals is indicated not only by the clumsy shape, and large size of the heavily armored head, but also by the absence of an axial skeleton, and by the feeble development of the trunk and the dorsal and caudal fins.

The overlapping of the large scales on the dorsal surface of the trunk in Cephalaspis, and the presence of minute ventral scales, indicate some freedom of movement in a dorso-ventral direction and a restriction of those lateral movements so essential to sustained swimming when well developed appendages for that purpose are absent.

The dorsal fin was short and low and covered with close set scales that would allow but little freedom of movement.

The Cephalaspidæ, therefore, were in all probability bottom feeders. Any one that has watched Limuli, both old and young, ploughing slowly through the soft mud and sand, leaving little more than their median ocelli and lateral eyes exposed, could hardly avoid the conclusion that many of the trilobites and Cephalaspidæ, whose eyes are placed high up on the convex surface of similar shovel-shaped heads, must have moved about on the bottom in a similar manner.

But Limulus frequently crawls with considerable rapidity over the surface of shallow bottoms, or turning on its back with the aid of its caudal spine, even the largest and heaviest female may leave the bottom and swim slowly away with legs, operculum and gill covers beating the water in unison with oar-like strokes. The young larvæ, especially in the trilobite stage, swim very persistently in this inverted manner. It is also well known that Branchipus, Apus and many copepods swim in this position, and there can be but little doubt that many trilobites and merostommata did the same.

The Cephalaspidæ were certainly disproportionately heavy at the anterior end, so that any attempts to swim by movements of the trunk alone would tend to push the head deeper into the mud or sand, a tendency that would be increased by the sharp downward slope of the anterior dorsal surface. It is also probable, judging from the shape of the head and trunk, that its centre of gravity was situated above the mass centre, so that if the animal did succeed in getting off the bottom, it would have a

tendency to topple over and thus bring the ocular surface underneath. In this position, however, owing to the convexity of the surface, now underneath, any forward movement would tend to elevate the head and thus counteract the effect of its greater weight and volume.

When the Cephalaspidæ, therefore, left the bottom they probably turned over on to the ocular surface and made their swimming excursions in much the same manner as the above mentioned arthropods.

Whether the locomotion of the Cephalaspidæ was aided by the movements of branchial appendages concealed beneath the arching under surface of the head, can only be determined by the study of more perfect remains than have been as yet discovered. Certainly the very strongly concave under surface of the head indicates the presence there of some organs freely movable and of considerable size, projecting ventrally and laterally from the middle region of the head.

What we have said in regard to mode of life of the Cephalaspidæ will apply, with slight modifications to other members of the ostracoderms.

The Asterolepidæ, with their powerful, but badly constructed and impractical appendages and large centrally placed eyes, represent the extreme development of the free swimming type. It is quite certain that in some genera the attachment of the slender swimming appendages close to the ventral side, and the very highly arched dorsal surface, must have made it extremely difficult, if not impossible, for these animals to swim with the ocular, or dorsal surface, uppermost.

The methods of locomotion in the ostracoderms and the arthropods thus have a double value for they show us that animals like Limulus, the Phyllopoda and probably the Trilobita and the Merostommata, adopted when swimming a vertebrate position with the neural side uppermost, and that the ostracoderms must have frequently assumed the typical invertebrate position.

In Pteraspis, Cyathaspis and Tolypelepis, the lateral eyes are probably absent, or were covered with such thick layers of the shell as to render them nearly useless. The trioculate median eye, however, is well developed and is represented in Pteraspis.

by a small pit on the under side of the dorsal shield, in Tolypelepis by an inconspicuous smooth spot on the outer surface, and in Cyathaspis by three obscure markings. These conditions indicate a considerable degeneration of the visual organs in these genera and must have profoundly modified their mode of life toward one of less activity and greater simplicity. We have here a condition approaching that of the lampreys, where the lateral eyes may be nearly functionless, while the median ones attain a degree of development that is hardly exceeded by that in any other vertebrate.

In Cephalaspis, the mouth was almost certainly situated high up on the vaulted under surface of the head and the character of the mandibles, as well as the small space into which such organs must have been crowded indicates that the mouth was very small. Similar conditions prevailed in Trematapsis, Bothriolepis and other members of the ostracoderms. Under these conditions and with their necessarily slow and clumsy movements, the ostracoderms could not have been rapacious animals. The position of their eyes, whether well developed or not, points with equal decisiveness to the same conclusion, for whether swimming or crawling, they could not see where, or when, to seize their prey, because their eyes would always be behind their own body. They must have been dependent on highly specialized gustatory, or tactile, organs situated near the mouth.

As a parasitic life for such animals is out of the question, it is probable that they lived on the soft bodied animals or decomposing organic matter that could be exposed or forced into the mouth as they slowly ploughed their way through the soft mud or sand.

DARTMOUTH COLLEGE, HANOVER, N. H.

July 10, 1903.

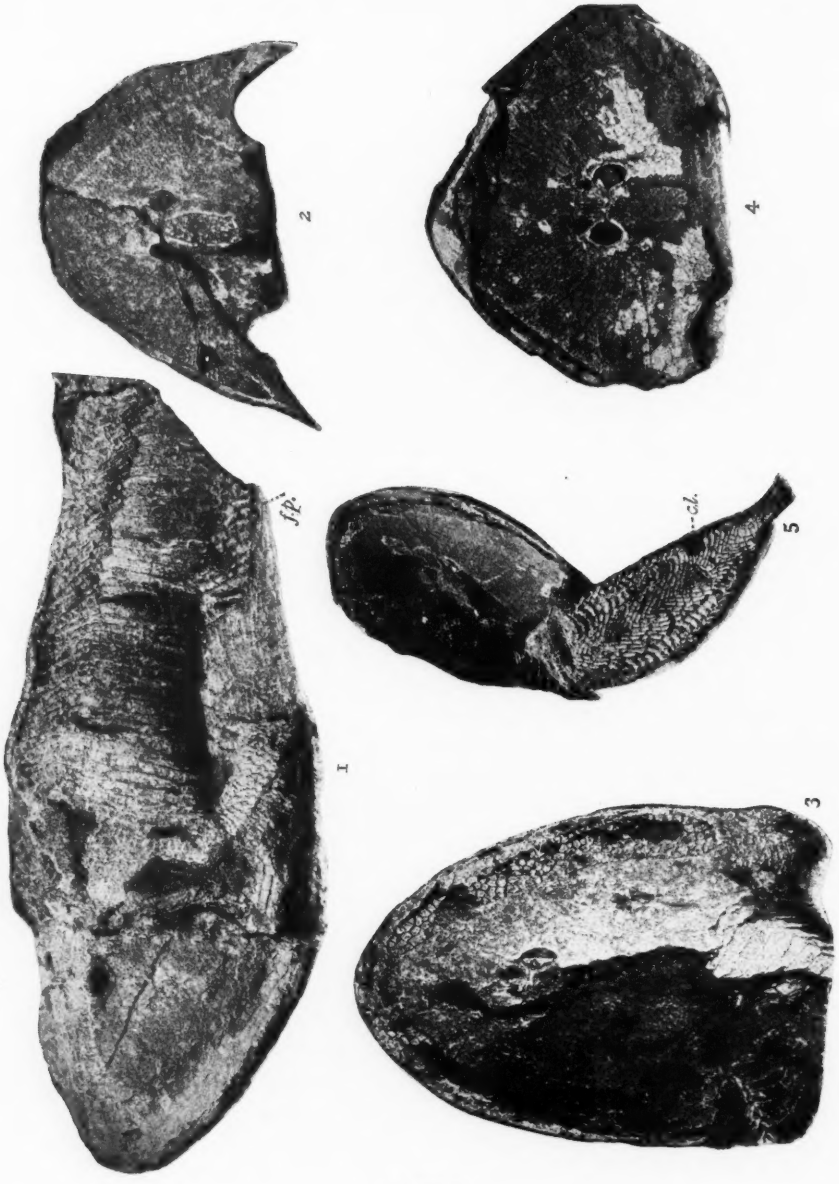


PLATE I.

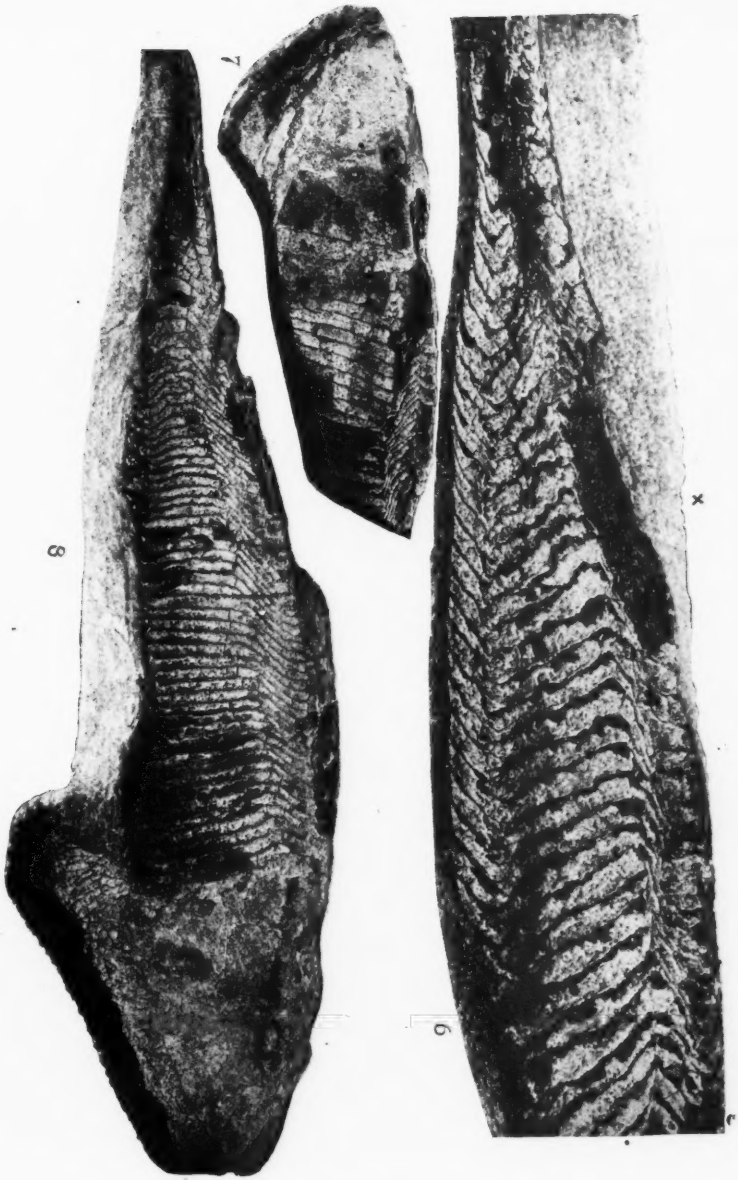


PLATE II.

Explanation of Plates.

PLATE I.

Fig. 1.—*Cephalaspis murchisoni*, showing several lobed fringing processes, *fp*. British Museum.

Fig. 2.— Head of Cephalaspis. Outer layers of the shell are absent, showing outlines of the bony trabeculæ below the lateral openings and the post-orbital valley.

Fig. 3.— Shows outline of the lateral openings filled with polygonal plates. British Museum.

Fig. 4.— Shows the impressions of radiating blood vessels on the inner surface of the shield. British Museum.

Fig. 5.— Ventral surface of the trunk of Cephalaspis, showing the cloacal opening.

PLATE II.

Fig. 6.— Side view of the trunk of *Cephalaspis lyellii*, showing the fringing processes and their articulation with the lateral trunk scales. British Museum.

Fig. 7.— Head and anterior portion of the trunk of Cephalaspis, showing arrangement of the trunk scales. British Museum.

Fig. 8.—Side view of head and trunk of *Cephalaspis murchisoni*. British Museum.

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AN OUT-DOOR EQUIPMENT FOR COLLEGE WORK IN BIOLOGY.

JAMES G. NEEDHAM.

THE study of living nature is chiefly manifest at the two extremes of our educational system in the establishment of public school gardens and university summer laboratories. Of what is being done in this line between the grades and the graduates less is heard. Perhaps it is because the high school and the college are less prone to advertise themselves by novelties in their educational programs: perhaps, because they are seeking to develop new methods instead of creating them full fashioned outright.

Thus far, the grades that have acquired good school gardens seem to have the better of it. For, besides having established an inexhaustible and ever accessible base of supplies for nature study work, they have at the same time set the pupils enthusiastically to educating themselves, and by the historic method — by doing over again in the garden such work as was done when the mental fibre of the race was first toughening.

The situation in high schools seems less fortunate. While many of them have books outlining ecological phenomena, very few of them have proper opportunity for the study of such phenomena. The grounds of the average high school are the most drear and barren waste within the city limits. The life that belongs to the soil has been exterminated. Only trees are cultivated, and these are not often native trees. The birds are English sparrows: the animals are stray cats, mice and roaches. If there be parks in the city no natural assemblage of native plants and animals is to be found therein: for the taste of the average town has not evolved beyond the painting-the-lily stage. By means of long rides on street cars at infrequent and uncertain intervals classes are taken out to see some remnants of nature and are shown things. The best thing found

is often fresh air. How far this falls short of the individual work that may be done in the school garden or at the laboratory table! The too common result of giving suggestions for seeing things that there is no opportunity for seeing is a relapse to book-and-recitation methods.

The field laboratories of the universities offer for the most part excellent opportunities both in natural environment and in facilities for its study; but these are far from home and available

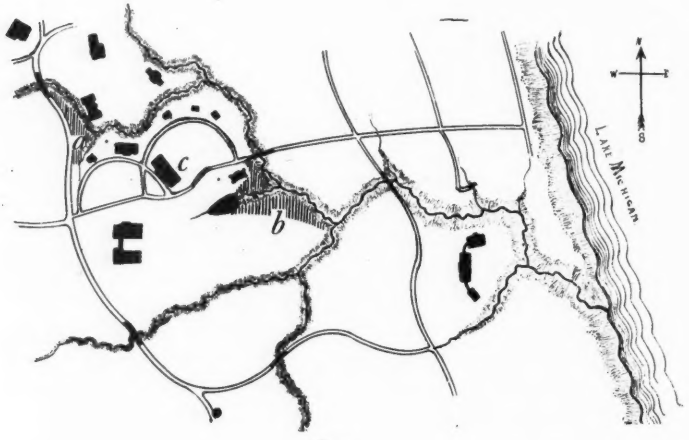


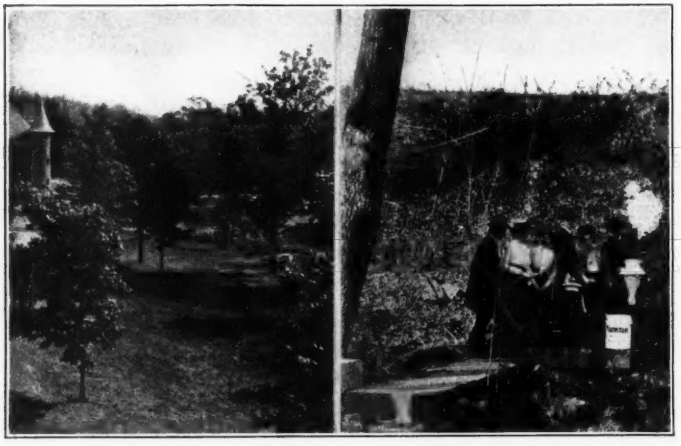
FIG. 1.

only in the summer vacation, and the rank and file of university students miss altogether the sort of training they afford.

Very little is heard of the movement toward the utilization of living nature in college work, yet it is exerting a powerful influence over present methods. The anatomical work which was the beginning, the continuation and the end of the old time courses laid out by morphologists — and morphologists must be given credit for having laid out the first practical laboratory courses — no longer monopolizes all the time of the general student. The elements of biology that make for culture are far from being confined to the dissecting table. And more and more college students are being encouraged to study nature in the field and by those methods that in the last century yielded our most important generalizations.

This article is intended to set forth some of the ways in which living nature is utilized at Lake Forest College, where the work is not that of a summer season spent far from home, but that of daily college life, done about the doors of the college halls; not the research work of graduates, but the general-culture work of undergraduates; not for the few who can afford it, but for the many who need it.

The plan here has been to use things near at hand. In a large measure, therefore, the situation accounts for the things that have been done. The accompanying map (Fig. 1) of the campus and its immediate environs shows some of the determining physiographic conditions. The campus is situated on the scarcely perceptible eastward slope of a terminal moraine, which parallels the shore of Lake Michigan, and is covered with fine oak woods. It is intersected by sharp ravines that have been cut by puny postglacial streams. The ravine shown in the map is scarcely more than a mile in length, and attains a depth of about 70 ft. where it reaches the lake level at its mouth. On the ridge at the head of these streams is a series of shallow ponds, many of them temporary, and some of them doubtless occupying old "buffalo wallows." Half a mile farther westward the Skokie winds its leisurely course through the marshes at the foot of the more abrupt westward slope of the moraine. The Skokie and its marshes, the ponds, the upland woods, the ravines, the crumbling outer face of the "bluff" and the Lake Michigan beach, each furnishes its own peculiar fauna and flora, and all are within easy walking distance of the campus. But the woods, the ravines, and an artificial pond are upon the campus, and are as easily entered for study as are the laboratories: and, naturally, these are most used. In the map *c* is college hall, the building in which the biological laboratories are located, and *p* is the pond — perhaps the most important single feature of biological equipment — a veritable aquarium, permanently stocked and self sustaining — teeming with a multitude of forms of animal and plant life. Its proximity may be judged from the view shown in the first figure of the plate, which view was taken from the window of the general laboratory. The heavily shaded portions of the campus (*a* and *b*) comprising sev-



The campus pond.

Washing down a catch.

The winter house.

eral acres extent, have been set apart by the trustees for the purposes of a biological garden. Both plots are wooded and traversed by deep ravines. Plot *a* being at the front of the campus is to be used chiefly for ornamental planting of native shrubs and trees. Plot *b* is more secluded, and is more freely used for the ends of biological instruction. It contains the pond, and the winter house shown in the third figure of the plate. Its ravines exhibit, especially on the shady side, a luxuriant tangle of shrubbery and vines, of flowers and ferns, so little disturbed by civilizing influences that the native *Cypripedium reginæ* and *Adiantum pedatum* — usually the first victims of their loving friends — still flourish there abundantly. The first thing done in this plot was taking measures to preserve the native species still present, and to restore to it a number that had been already exterminated. The next thing, was the assembling of those biological and ecological types especially useful for illustration in general course work. Plants are raised here not for themselves alone but for the sustenance they afford to the forms of animal life desired to be retained with them. Care has been taken to provide a constant succession of wild fruits for birds, the proper plants to sustain aphid colonies with change of hosts, and for the food of particular animal species — even for a solitary aboriginal family of woodchucks. Thus, where nature had done much, and where the material needed was all near at hand, attention has been given to making things as readily available for study in the field as they are in the laboratory, to the end that field studies that are really worth while might be undertaken.

But two things that are obviously artificial have as yet been introduced into the garden: a plankton apparatus and a winter house. Probably no college teacher has witnessed a good plankton catch at a summer laboratory or field station without wishing that such quantities and variety of the simpler organisms might be available for his class-room work. Many of them may be obtained, to be sure, with any simple sort of towing net; but an apparatus that will get all the life at a definite depth and serve for quantitative measurement of it has generally been accounted too complicated and too expensive for the equipment

of an average college. But an apparatus that will do all these things and that will gather in a few minutes use more plankton than can be even qualitatively examined in a laboratory period, was constructed by several student assistants a Lake Forest College at a cost of about ten dollars.

The exterior of the apparatus is shown in Fig. 2 and the net itself is seen in the second figure of the plate. A net of the usual form was made of no. 20 silk bolting cloth. A large milk can with loose breast and heavy steel cap was used to sustain the net and to hold the slack water in which it should rest while

FIG. 2.— A simple plankton apparatus.

receiving the inflow stream. The net itself is suspended from two perforated circular brass strips soldered within the upper and lower edges respectively of the breast. To a short tube inserted into one side of the breast is attached the waste pipe *q*. The intake pipe *r* is attached to the cap; but a three-way cock is inserted in the couplings at *c*, and a short pipe *p* is attached to its lateral aperture, with a spray nozzle on the end. The cock may be turned so as to stop the flow altogether or to direct the stream laterally through the spray pipe *q* (as shown in action in the second figure of the plate) or to direct it through the cap

into the net and out through the overflow pipe *q*. The rate of flow is readily measured at the end of the overflow pipe *q*. The net is placed for use on a platform at the foot of the dam that confines the campus pond and the water is brought to it by siphoning over the dam with a long garden hose. The upper end of the hose is fitted with a funnel-shaped, screen covered intake, and this can be held in any position and at any depth as long as desired. The flow is perfectly uniform, even such active and light loving forms as Corethra and Corixa being readily taken down the pipe. This simple apparatus has made itself an indispensable adjunct to the work of several courses. Its use at once revealed the presence of vast numbers of Dinobryon, Notholca, Polyarthra, etc., not previously known to exist in the pond.

Near to the plankton platform in the ravine is the winter house, in which are kept the plankton and other field apparatus and garden tools. Here are proper quarters also, for live animals desired for study during the winter: tanks in the floor for salamanders, frogs, crayfishes, earthworms; shorts-bins on the wall for meal worms, sand beds for seeds and for plant cuttings, etc. This most useful little house, shown in the third figure of the plate, was built to fit the landscape and not to disfigure it.

Individual apparatus for field work is much more simple. Air and water nets, cyanide bottles, jars and vials, garden trowels, etc., are supplied every student; for field work at Lake Forest is just as individual as is laboratory work, and just as definite results are expected from it. How much less expensive is this out door equipment than the indoor equipment that all the colleges have!

But the first requisite of satisfactory field work on the part of college students is neither books nor apparatus, but living nature near at hand. Fortunately, the native plants that are needed will grow near at hand, if given room, and their natural animal associates — at least those most useful for study — will come and dwell again with them. Fortunately, also, they may be made to add both beauty and interest to the grounds devoted to them. Though the environment at Lake Forest is exceptionally favorable for all this sort of work, it is to be borne in mind

that nine tenths of what is undertaken here could, with proper provision, be done anywhere. Ecological types are as widely distributed and as available for study in different places as are morphological types: and biological phenomena are as tangible and as real as are systematic, while certainly not of less interest or educational value.

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Lake Forest College.

PRELIMINARY REPORT ON THE "PALOLO" WORM OF SAMOA, EUNICE VIRIDIS (GRAY).[1]

W. McM. WOODWORTH.

SINCE a Monograph of Samoa would not be complete without some account of the "Palolo," at Dr. Krämer's request I have prepared the following summary, reserving for a subsequent publication a detailed account of the "Palolo" and other annelids of the coral reefs of the Pacific. In this preliminary paper I can only touch upon historical matters and the often written story of the "rising" and "fishing" of the "Palolo," referring the reader to the publications of Collin,[2] Friedlaender,[3] Krämer,[4] and Ehlers.[5]

The "Palolo" has been known to naturalists for more than half a century and much has been written about it in a fragmentary way. It was, however, during the period of Krämer's investigations in Samoa that its true history was brought to light, and

[1] This provisional account prepared for Krämer's monographic work on the Samoan Islands (Krämer, Augustin, *Die Samoa Inseln* etc. Stuttgart, E. Nägele, 1903, Bd. 2, pp. 399–403) and translated by him into German, is reprinted here with some changes and corrections. The author has in preparation an extended study of the life history, morphology and distribution of the "Palolo," and allied Eunicidæ.

[2] Collin, A. Bemerkungen über den essbaren Palolowurm, Lysidice viridis (Gray). Appendix to Krämer's *Bau der Korallenriffe* pp. 164–174.

[3] Friedlaender, B. Über den sogenannten Palolowurm. *Biolog. Centralblatt.* Bd. 28, p. 337–357. 1898. — *Idem*, Notes on the Palolo. *Jour. Polynesian Soc.* Vol. 7, p. 44–46; Wellington, N. Z. 198. — *Idem*, Nochmals der Palolo etc. *Biolog. Centralblatt.* Bd. 19, pp. 242–269. 1899.

[4] Krämer, A. *Über den Bau der Korallenriffe und die Plankton-verteilung an der samoanischen Küste nebst vergleichenden Bemerkungen.* Kiel und Leipzig 1897.— *Idem*, Palolountersuchungen. *Biolog. Centralblatt.* Bd. 19, pp. 15–30. 1899.— *Idem*, Palolountersuchungen im October und November 1898 in Samoa. *Ibid.* pp. 237–239. 1899.

[5] Ehlers, E. Über Palolo (Eunice viridis Gray). *Nachr. K. Ges. Wiss. Göttingen. Math.-naturw. Kl.* 1898. pp. 400–415.

much of our knowledge of this interesting worm is due directly to him and to the stimulus of his work. The first extended account was written by Collin[1] as an appendix to Krämer's earlier work on Samoa. In this account Collin, with previous writers, considers the "Palolo" to be the posterior part of *Lysidice viridis* (Gray), a few detached heads of which had from time to time been taken with the "Palolo" at the 'fishing' season, and as no other annelid heads were taken with the "Palolo" and all "Palolo" were headless, it was natural, for want of better evidence, to ascribe the "Palolo" to the genus Lysidice. The discovery of the origin of the "Palolo" was made independently by Krämer and Friedlaender, although the latter was the first to publish an account of his investigations.[2] Friedlaender succeeded in obtaining from the reef rock at Samatau several specimens of "Palolo" together with the head ends of an annelid of different appearance and much larger size belonging to the genus Eunice. His material was afterwards studied by Ehlers[3] who recognized an extreme case of sexual dimorphism and showed the "Palolo" to be the epitokal posterior portion of *Eunice viridis* (Gray). Ehlers says, "Ich ergänze das im Voraus damit, dass ich die Eunice, die nun den Namen *Eunice viridis* (Gray) erhält, in den Kreis der Eunice siciliensis Gr. bringe und an ihr die Ausbildung des "Palolo" als eine Form der Epitokie auffasse, wie sie zum ersten Male aus der Familie der Euniciden, und in ihrer Besonderheit abweichend von allen Erscheinungen der Epitokie, die von Borstenwürmern bekannt sind, sich darstellt. Demnach ist in der Art eine atoke und epitoke Form, in der letzteren eine atoke und epitoke Körperstrecke zu unterscheiden."

It was my good fortune to be at Levuka in the Fiji Islands during the "rising" of the "Palolo"[4] in November, 1897, where I gathered much material and information, and in the following year went to Samoa to learn more about the history of this

[1] *Op. cit.*

[2] See Thilenius, G. Bemerkungen zu den Aufsätzen der Herrn Krämer und Friedlaender uber den sogenannten Palolo. *Biol. Centralblatt*, Bd. 20, pp. 241–242, 1900.

[3] *Op. cit.*

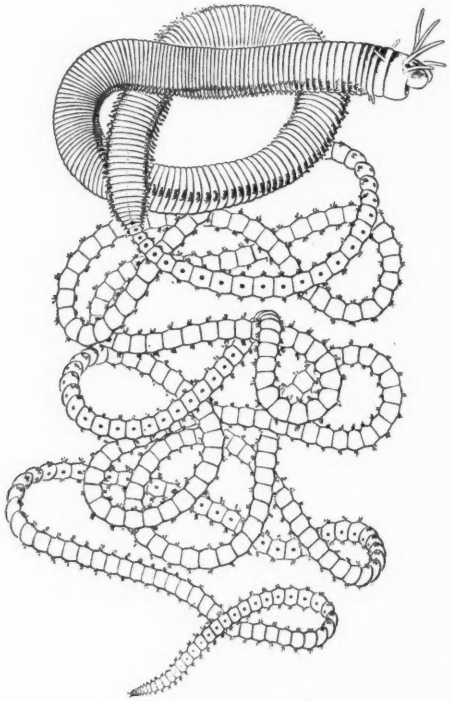
[4] Bololo, pronounced Mbololo in Fijian.

mysterious worm. I arrived at Apia on October 20 and was fortunate in meeting Dr. Krämer who placed at my disposal the notes he had collected during three years in the islands. I made my headquarters in the village of Falelatai on the South side of Upolu a little to the eastward of Samatau where Friedlaender obtained his material. After several days of fruitless search on the reef between Samatau and Falelatai my native friends took me to a shallow bay called Fagaiofu about two miles east of our village. The bay lies between two small promontories and is about one quarter of a mile wide, the distance from the shore to the edge of the fringing reef, which fills the bay, is not more than 150 meters. The place is so shallow that at low tide one can wade from the shore to the edge of the reef. The reef platform, which is composed chiefly of dead coral and honeycombed reef rock, is interrupted by two narrow deep channels or passages.

The reef at Fagaiofu proved to be literally alive with "Palolo." They were discovered by prising off, with a crowbar, masses of the rock at the edges of the channels. They could be seen dangling from the freshly exposed surfaces and wriggling free into the deeper water of the channel to be carried seaward by the retreating tide, to the astonishment of my natives who had never seen the "Palolo" before the time appointed for its appearance — this was three days before. Owing to the great length of the entire worm, its fragile structure and intricate association with the cavities of the honeycomb rock, the operation of freeing unbroken specimens is a delicate one. With the aid of chisels and forceps I succeeded with great difficulty in obtaining, in addition to other material, three worms complete from head to tail.

My experiences confirm the discoveries of Krämer and Friedlaender as to the origin of the "Palolo." The accompanying figure, which is drawn to scale, shows the complete animal, the broad anterior atokal portion being sharply marked off from the more attenuated and much longer posterior epitokal part which, when free-swimming, is known as the "Palolo." The total length averages 400 mm., about one fourth of this length being in the anterior atokal part. 429, 359, and 250 atokal segments were counted; the first two in male specimens the latter in a

female. These figures are not accurate as a dense gelatinous secretion in the posterior part of the atokal region makes it difficult to count the segments. The greatest diameter of the atokal region is 4 mm. and that of the epitokal region 1–1½ mm. diminishing gradually at the anal end, and more abruptly at the junction of the atokal and epitokal parts. The color of the male is



Eunice viridis (Gray). The narrow posterior epitokal part when detached and free-swimming is known as the "Palolo." × 2.

reddish brown, that of the female bluish green. These colors, which are very marked in the epitokal portions are due to the colors of the sperm and ova; after the discharge of these elements the collapsed integument is translucent and colorless. These distinctive sexual colors are also present in the atokal parts but are not so marked, the female being more greenish in

hue than the male; the colors here are integumentary. Each of the epitokal segments bears on its ventral surface a prominent pigmented spot, the "Bauchauge" of Ehlers. These eye spots can be traced into the atokal part through about 20 segments, diminishing in size toward the anterior end; they are lacking on the anal segment and are usually absent in 2–6 of the preanal segments.

A similar swarming of marine annelids, and at corresponding seasons, is known for other islands of the Pacific, though the worms have not everywhere been identified. Powell[1] speaks of them in the Gilbert Islands where they are known to the natives as *te nmatamata* and Codrington[2] gives a detailed account for Mota in the Banks Islands where they are known as *un*.[3] Brown[4] mentions an annual appearance of a "Palolo" on the East coast of New Ireland, and the *wawo* of Rumphius which occurs at Amboina in the Moluccas is doubtless the same, as has been pointed out by Collin.[5] Seeman[6] mentions the occurrence in the New Hebrides, and it is known in Fiji and Tonga. It is reasonable to suppose that a systematic search would show the "Palolo" or some allied form to have a wider distribution in the coral reefs of the Pacific than has been as yet recorded. That the annelid is best known from Samoa and Fiji is accounted for by these two groups of islands having been most visited and longest inhabited by whites. It is significant also that such records as we possess from other places, though meager, have come to us through the missionaries, the pioneers of intelligent whites in the islands of the Pacific.[7]

[1] Powell, T. Remarks on the Structure and Habits of the Coral Reef Annelid Palolo viridis. *Journ. Linn. Soc. London.* Vol. 16, pp. 393–399. 1883.

[2] Codrington, R. H. *The Melanesians. Studies in their Anthropology and Folk Lore.* Oxford 1891.

[3] Doubtless the *a'oon* of McIntosh.

[4] Brown, G. Notes on the Duke of York Group, New Britain and New Ireland. *Journ. Roy. Geog. Soc.* Vol. 47, pp. 137–150. 1877.

[5] *Op. cit.*

[6] Seeman, B. *Viti. An Account of a Government Mission to the Vitian or Fijian Islands in the Years 1860–1861.* Cambridge 1862.

[7] Cases of swarming associated with extreme sexual dimorphism have been described for a Eunice from Florida (Mayer, A. G., *Bull. Mus. Comp. Zoöl.* Vol. 37, 1900) and for one of the Lycoridæ from Japan (Izuka, A., *Journ. Coll. Sci. Imp. Univ.* Tokyo, 1903).

The "Palolo" makes its appearance in Samoa in the months of October and November during the last quarter of the moon. This is the time of the lowest or spring tides when the reef flats in shallow places are uncovered or only awash, and at this season the sun is nearest to the zenith. I must reserve for my final paper a discussion of the causes of the swarming of the "Palolo" and will only say here that I am inclined to believe in some thermotropic or heliotropic reaction of the eyes borne on the ventral segments of the epitokal part of the worm. These eyes have recently been studied histologically by Hesse[1] on material collected by Krämer. Hesse states that from their structure the eyes probably do not form images, but function rather in reacting to light of different intensities, the direction of light and possibly to different colors. It is significant that these eyes are found only on a few of the posterior segments of the atokal sedentary part and are not well developed; while on the other hand they are highly developed on all but the anal segments of the epitokal active part which leads such an ephemeral free existence.

This spring season is recognized as the period of ripeness and sexual activity throughout the Pacific Islands and where the "Palolo" occurs the season and even the months are named for it. All of the many other kinds of annelids inhabiting the reefs are sexually mature as shown by the extensive collections made by Krämer and myself in Samoa and Fiji and this is true also of the reef fauna in general. The spawning time of the land crabs, the occurrence of certain fish, etc., is reckoned by the natives as so many days before or after the "Palolo," and so for the appearance of blossoms the ripening of fruits and tubers. In Samoa the "Palolo" season is called *taumafamua* (*i. e.* the time of much to eat), in the Banks Islands they say "*tau matua* the season of maturity, yams can be eaten."[2]

The "Palolo-time" in Samoa embraces three successive days. When in the last quarter of the moon in October and November, more especially the latter, the water on the "Palolo-grounds"

[1] Hesse, R. Untersuchungen uber die Organe der Lichtempfindung bei niederen Thieren. V, Die Augen der polychaeten Anneliden. *Zeitschr. wiss. Zool.*, Bd. 65, pp. 459, 1899.

[2] Codrington, *op. cit.*

has a turbid or riled look, with floating patches of scum, the natives know that two days later the "Palolo" will 'rise.' This first day is called *salefu*. The second day is marked by the swarming of a small annelid, headless like the "Palolo," and the sexes distinguished by the same yellow and greenish tints. This day is called *motusaga*. The third is the *tatelega* when the "Palolo" swarms and the natives come many miles to the favored places to gather it. With "Palolo" of the *tatelega* day many of the small annelids of the *motusaga* occur, and a few "Palolo" appear on *motusaga* day. A microscopical examination of the *salefu* scum shows it to consist of a gelatinous slime in which are grains of sand, appendages, fragments and casts of Entomostraca and a varied detritus of the seething life inhabiting the reefs, including many ova of various kinds in different stages of segmentation. The *salefu* may be looked upon as a manifestation of the awakening of the "Palolo" previous to its swarming or marriage-swim; an annual activity of countless numbers of annelids resulting in a discharge into the water of the deposits accumulated in the galleries and crevices of the reef-flats. The small annelid of *motusaga* day is *Lysidice falax* Ehlers, the *L. viridis* (Gray) to which the "Palolo" was so long ascribed.

CAMBRIDGE, MASS.
August, 1902.

FURTHER NOTES ON THE HABITS OF AUTODAX LUGUBRIS.

WM. E. RITTER.

WITH the information about the breeding habits of this salamander obtained by Mr. Miller and myself during the summer of 1899[1] we supposed that in succeeding seasons we should have little difficulty in securing sufficient eggs to enable us to make a fuller study of its development. The next summer, consequently we, and particularly Mr. Miller, searched for the eggs constantly and carefully under logs and rocks and in half decayed stumps all about the San Francisco Bay region, but not a single egg rewarded our efforts. I have kept up the quest each year since, but not until the present summer has anything but failure come of it. Now, wholly by accident, the usual breeding place of the species, for this locality at least, appears to have been found. *This turns out to be holes in trees.* The one positive, and one doubtful, instance reported by us of egg-laying in the ground seems to have been exceptional.

In caring for the oaks (*Quercus agrifolia*) on the campus of the University of California this summer the trees have been subjected to a treatment they have never before received. This has consisted in the careful cleaning out of the decayed wood and foreign accumulations from all accessible corners and cavities, and of painting the walls of these with coal tar, and then filling the smaller cavities with Portland cement. The men engaged in the work have taken from these holes about 100 specimens of the salamander itself, and twelve bunches of its eggs.

The form-habit of this oak commonly spoken of as the "live oak," is well known to all who are acquainted with the environs

[1] Ritter, Wm. E., and Miller, L. H. A Contribution to the Life History of Autodax lugubris Hallow, a California Salamander, *Amer. Nat.*, Vol. 33, 1899, p. 691.

of San Francisco Bay. The tree is short trunked, and diffusely branched, the contorted branches being wide spreading rather than high reaching, so that a height of fifty feet is exceptional. The salamanders are found as high in the trees as there are holes suitable for their dwelling places. Some have been taken from holes at the height of thirty feet at least. In some of the largest cavities as many as twelve individuals were found; more commonly, however, a hole contained two, or occasionally but a single one.

Several facts indicate pretty clearly that in some cases all the inhabitants of a single chamber were close of kin, constituted in fact, a family. Where a considerable number of individuals were together it invariably happened that the majority were small, and the particularly significant thing is that the small ones were all of about the same size, their length being about 50 mm. Besides these individuals of minimum size there occurred in nearly all the inhabited holes whether containing the small ones or not, a few, usually two, individuals of maximum size. Then in addition to those of maximum and minimum size, there were frequently found, in the same hole, several others of intermediate size. Those of minimum size constituted in all probability a single litter, and were at this season of the year, viz., early autumn, yearlings. Furthermore, I strongly suspect they were frequently, if not always, the young of the individuals of maximum size occurring in the holes with them. If this interpretation of the meaning of the presence of the small individuals together is correct, it would follow that they had probably never yet in the year of their existence left the tree in which they were hatched. It is hardly to be supposed that they could make nightly excursions to the ground and return to the same hole to spend the day. As was pointed out in the paper above cited the species is distinctly nocturnal. As a rule the cavities occupied by the animals while of ample dimensions for creatures of their size, had but very small orifices by which entrance could be effected from the outside world. Frequently the opening was not more than three or four centimeters across, barely larger than necessary to admit the body of the full grown animal. But for the directions the workmen had received to carefully clean to the

bottom all the cavities they could find, even though the entrances had to be cut larger in order that the remedial treatment might be administered, the dwelling places of the salamanders would surely not have been found. Wide mouthed cavities were rarely found occupied.

The egg clusters, each containing from twelve to eighteen eggs, and each egg with its own pedicle about two centimeters in length were usually suspended from an overhanging surface where the parent was able to bring its body into contact with them. This it did by winding itself around the egg clusters in much the same way that several other species of Urodela are known to do. More than one bunch of eggs rarely occurred in the same hole.

Several observations make the question of the extent to which parental care of the eggs and young may go in this species, one of much interest. In the first place it appears that the male and female may both together participate in the office. Probably a majority of the cavities in which eggs were found contained two animals of maximum size. In some instances at least these were certainly male and female. Whether this was always or usually the case or not I am not yet able to say, since, this point not having been raised until most of the animals taken had been put together in a common terrarium, it was impossible to tell which were inmates of the same hole. It may be noted in this connection that there are no secondary sexual distinctions in this species, so far as I have been able to determine.

Again the animal seems to exercise more or less of an active defence either of itself or of its eggs or both. Its unusually large teeth has been a subject of comment by nearly all zoölogists who have written about it,[1] and in the paper by Miller and myself attention was called to Cope's statement that "this Autodax is probably more capable of inflicting a bite than any other of the American salamanders." At that time we were obliged to say, however, that "we had not been able to get any positive

[1] Cope for example, (*The Batrachia of North America*, p. 182), remarks that "this curious genus is furnished with by far the most powerful dentition of any existing salamanders, and resembles in this respect the genera of the Coal Measures, Brachydectes, Hylerpeton, and Hylonomus."

evidence on the point." The workman who found most of the specimens in the holes tells me, without having been questioned with reference to the matter, that the old ones with the eggs usually "showed fight" when he first came upon them. He says they seized a stick or his finger when held toward them with decided energy. I have, furthermore, the direct testimony of another person, in this instance a student well experienced in out of door natural history, that an individual once found by him under a rock or log in the field, seized his finger in a distinctly vicious manner.

Thus is brought to light more of the peculiar traits that have attracted the attention of several observers of this unsalamander-like salamander. So far as I am aware this is the only urodele that could properly be called arboreal.

These peculiarities are the more interesting in that there can be no question as to the real affinities of the species. Its close kinship to the other plethodons can not be doubted for an instant. All that is unique about it, it has acquired so far as can be seen all by itself. Experimental study on its behavior should, consequently, yield unusually interesting results.

UNIVERSITY OF CALIFORNIA.
Sept. 15, 1903.

A TRIP TO THE TRUCHAS PEAKS, NEW MEXICO.

WILMATTE PORTER COCKERELL.

THE high mountains of Colorado are continued southward into New Mexico without a break as far as the region of Santa Fe and Las Vegas. Some distance north of this, however, the range forks, presenting roughly the form of a reversed Y. One of the arms of the Y is known as the Las Vegas Range, the other as the Sante Fe range. The Truchas Peaks are in the Sante Fe Range and represent almost the southernmost extension of the Arctic-alpine zone.

The first week in August, 1902, I visited these peaks and collected both flowers and insects. There is no road into the region; and from Blake's ranch, which is just inside the Pecos Forest Reservation we secured a guide, saddle horses and pack animals. The first day we passed over the Las Vegas Range, travelling through beautiful alpine meadows and great stretches of spruce forests. Travelling through this country was very delightful and the long vistas of mountain slopes, with here and there the sparkle of an alpine lake, more than compensated for hard parts of the trail where the horses must be guided carefully as they jumped over the fallen trees. In places where the fire had destroyed the trees the hillsides looked much like a board covered with jack-straws and even our skilful guide sometimes led us into boxes out of which our horses could not climb and we were obliged to retrace our steps and try a new path.

Our first camp was on the Mora fork of the Pecos River: this is a small but very rapid stream that heads in the Truchas, and it is famous through all northern New Mexico for the size and number of trout that it contains. We saw trout (*Salmo spilurus*) in great numbers but the stream was low and very clear so that only a few were hooked.

Some dark purple bells (*Campanula uniflora*) grew here

among the short grass which covered the open spaces of the valley. The next day's journey took us over grassy slopes dotted with bunches of mountain daisies; growing solitary or rarely in groups of two or three the yellow Mariposa lily (*Calochortus gunnisoni perpulcher*, Ckll.) opened wide its petals showing the purple and yellow center. Small dark bees industriously gathered nectar and pollen from these flowers. It was interesting to see the quick motions with which they pushed the hairs from the glands and sucked the nectar or climbed the filaments and loaded themselves with white pollen from the bursting anthers. The store house was so easily accessible and the stores so abundant that often the small bee overloaded itself and sank into the grass; then there was great buzzing and scrambling and throwing overboard of a part of the load before it could safely take to wing again. Here and there we saw the purple columbine (*Aquilegia cærulea*) with great splendid flowers of purple and white, though the plants were dwarfed like the plants of all high mountains.

Our second camp was made on the Pecos River, which in this region is about six feet across and very rapid. The river course is bordered with spruce with here and there an open grassy glade covered with a sort of bunch grass which proved excellent food for our horses. At the roots of this grass we found several small mice which moved with a curious quick creeping motion.

This grass was full of grass-hoppers, many of the species having no wings. Several large Megachile bees (*M. sapellonis*) were busy on the flowers here and *Argynnis eurynome* and *A. electa* flew from flower to flower. It was curious to see these butterflies going from glade to glade, for they would often rest in the boughs of the spruce trees, usually on the bright silver tips and here the wind would gently rock them back and forward and the sun would glisten on the silver spotted wings!

Along the river bank I collected a gigantic *Pedicularis procera*; it was almost six feet tall and had flowers an inch and a half long. Here we found great patches of Polemonium growing so closely bunched that no other plant could grow among them. There was one such bunch covering a space about ten feet square. A beautiful species of Actæa grew here but though

the plants were very large there were very few in numbers. Two species of Ribes, *R. wolfii* and *R. lentum*, occurred in the same vicinity.

August the second we climbed the peak to the northeast, and two days later the one farthest southwest. The slope was gradual so that by following the hogback we could ride quite out of timber. Here we found good grass for our horses and after securing them with lariats we left them to feed and walked to the mountain top. Just at the edge of the forest a great patch of gentians were growing along the trail; we had seen the fringed gentian and the bell gentian but this was our first sight of this high alpine flower. The leaves are short and form a thick mat on the ground and from this dark green mass the light lavender bells dotted with dark purple are lifted on a slender flower stalk two to four inches high. The species is *Gentiana frigida*.

A few hundred feet below the gentian field we passed over hillsides covered with splendid dark purple larkspurs (*Delphinium subalpinum*) there were acres and acres of this flower which varied from a deep purple marked with black to a very light purple ridged with white, and like the Polemonium the larkspur grows in thick clusters crowding out even the grass at its roots.

The southwest Truchas we found very difficult to climb and in places we pulled ourselves up by the bunch grass and held our places by digging our heels into the soft earth. All the plants were now reduced to mossy mats hardly more than an inch through.

A tiny primrose grew among the rocks; beautiful dark blue forget-me-nots (*Eritrichium argenteum*) with white woolly leaves and stems were abundant; a Sedum covered large acres and a little phlox (*Phlox condensata*) grew in the shade of the rock.

A bright reddish humming-bird rested on my shoulder. The butterflies flew with swift steady strokes, and were impossible to secure when on the wing. A large black Papilio flew past fluttering for a moment over the rock monument which marked the highest point of the mountain. The *Parnassius smintheus* flew about in numbers; some very worn and broken from long struggles with the high winds which usually prevail in these

mountain heights. *Argynnis eurynome*, very light green with yellow and silver markings underneath with dark ferruginous above trimmed abundantly with black, flew over the hillsides; the yellow and pink coloration of *Colias scudderi* added to the beauty of the scene. Bumble-bees and flies buzzed about our heads, and great gaudily colored saw flies tangled themselves in our hair. The ants were just swarming and under the rocks we found several species of beetles and spiders.

The view from the top was magnificent. Toward the west the great Rio Grande Valley could be seen bordered by hills which looked to be made of blue mist, so far away they lay. To the north, the south and the west were rugged peaks and wooded ranges everywhere marking the horizon off by curious zigzag lines. Two bald eagles flew through the space to our right — down and then up, darting and sailing and then across until they disappeared from sight.

NOTES.

List of Plants collected above timber line. Determined by T. D. A. Cockerell and Aven Nelson.

Eritrichium argenteum Wight, *Mertensia cœlestina* Nelson & Ckll. (a new species found on this trip [1]), *Saxifraga chrysantha* Gray, *Delphinium nov. sp.*, *Trifolium* sp., *Epilobium angustifolium* L., *Senecio holmii* Greene, determined by Mr. Greenman, *Gentiana frigida* Haenke, *Sedum stenopetulum*, *Veronica wormskjoldii* R. & S., *Phlox condensata* (Gray) E. Nelson, *Oxyria digyna* (L.) Camptdera, Draba *sp.*, *Castilleia haydeni* (Gray) Ckll.

List of insects collected above timber line.

1. Coleoptera. Determined by H. C. Fall. *Amara brunneipennis*, *A. femoralis*, *Tachys nanus*, Aleochara *sp.*, *Pachybrachys hepaticus*, *Hyperaspis fimbriolata*, *Galeruca externa*, *Aphodius aleutus*, Balaninus *sp.*

2. Diptera. Determined by D. W. Coquillett. *Lasiophthicus pyrastri* Linné, *Peleteria ænea* Stæger, *Trypeta occidentalis* Snow.

3. Hemiptera. Determined by O. Heidemann. *Corimelæna nitiduloides* Wolff, *Nysius angustellus* Blanch, *Geocoris limbatus* Stål., *Lygæus turcicus* var. *kalmii* Stål., Irbisia *sp.* near *brachycerus*, Uhler.

4. Lepidoptera. Determined by T. D. A. Cockerell. *Argynnis eurynome*, *Brenthis helena*, *Parnassius smintheus*, *Pyrameis cardui*, *Sciaphila*

[1] Described in *Proc. Biol. Soc. Washington.* March, 1903, p. 46.

argentana (det. by Dr. Dyar), *Colias scudderi flavotincta*, *Lycæna rustica*, *Plusia hochenwarthi*, *Colias eurytheme*.

5. Orthoptera. *Gomphocerus clavatus* var. *clepsydra*, *Melanoplus excelsus* (det. by Mr. Rehn).

6. Hymenoptera. Determined by T. D. A. Cockerell. *Bombus frigidus*, *Bombus ternarius*, *Bombus flavifrons*,[1] *Clisodon terminalis*, (on thistle).

7. Ants. Determined by Prof. W. M. Wheeler: — *Formica fusca subsericea*, *Formica* n. sp. (near *subpolita*), *Leptothorax canadensis*, n. var., *Myrmica rubra*, subsp.

Other species of various orders were collected, but have not yet been studied. The above is the first list of the fauna and flora of the Arctic-Alpine zone in New Mexico, excepting the records of insects taken on Taos Peak about thirty years ago by Lieutenant Carpenter.

LAS VEGAS, NEW MEXICO,
April 4, 1903.

[1] *Bombus flavifrons* is new to New Mexico. On the same trip, my wife took it also on the top of the Las Vegas Range (about 11,000 ft.). A male from the latter place represents a new variety: —

B. flavifrons var. *veganus*. Anterior part of thorax with yellow hair only; scutellum with a good deal of black; first two abdominal segments with yellow hair; third with black slightly mixed with red; fourth with red; the rest with black. Ventral surface of abdomen with yellow hair; some black hair on front, and on sides of face; some pale orange hair at base of mandibles. Malar space long; first and third joints of flagellum about equal, second conspicuously shorter. Tibiæ with yellow, tarsi with orange hairs. The yellow hair throughout is bright rather pale canary color. Mr. Viereck writes me about this: "There is n't a ♂ in the lot of *B. flavifrons* in the Cresson collection which tallies with your description of var. *veganus*, though the structure is the same. There are a few females which must look more like what you have, so far as pubescence goes. One small worker (9 mm. long) taken at Beulah by Dr. Skinner agrees even better than the specimens just cited, but has all the pale hair whitish. — T. D. A. COCKERELL.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS, RETIREMENTS AND DEATHS.

EDUCATIONAL GIFTS.

Amherst College, $100,000 from various sources for the astronomical observatory; an annual income of $1500 from Miss Pratt of Brooklyn.

Chicago University, $300,000 from various sources for researches in Egypt and Babylonia.

Columbia University, $40,500 toward the fund for the purchase of South Field.

Cornell University, $100,000 and the residuary estate by the will of Fredrick W. Guiteau.

Harvard University, $154,000 from various sources for Emerson Hall; $25,000 and half the residuary estate, for the Medical school, by the will of Dr. George Haven; $25,000 by the will of Richard W. Foster.

New Haven, a conditional gift of $300,000 from Andrew Carnegie for a public library.

University of Michigan, $4000 from J. B. Whittier for a fellowship in botany.

University of the Pacific, $100,000 raised by the California M. E. Conference.

University of North Carolina, $25,000 from Judge Wm. P. Bynum, $4000 from J. S. Hill.

Vassar College, a conditional gift of $200,000 from J. D. Rockefeller; $50,000 from other sources.

Washington & Lee University, $10,000 from Mrs. Cyrus H. McCormick.

Wesleyan University, $25,000 from Cephas B. Rogers.

Western Reserve University, $50,000 from various donors for the Women's College.

Wooster University, $100,000 from L. H. Severance.

Yale University, $100,000 by the will of Sarah B. Harrison; a metallurgical laboratory from John Hayes Hammond; $300,000 for a dormitory from F. W. Vanderbilt.

APPOINTMENTS.

Dr. Ralph Arnold, assistant on the U. S. Geological Survey.—C. F. Baker, assistant professor of biology in Pomona College, California.—Franklin D. Barker, instructor in zoölogy in the University of Nebraska.—Dr. Edward Bayer, custodian of botany in the Bohemian Museum at Prag.

— Prof. V. von Borbás, director of the botanical gardens at Klausenburg. — Dr. Max Borst, extraordinary professor of anatomy in the University at Würzburg.— Charles J. Brand, assistant curator of botany in the Field Columbian Museum.— Dr. F. Broili, docent for geology and paleontology in the University at Munich.— Dr. Alfred Burgerstein, extraordinary professor of botany in the University of Vienna.— Dr. Fridiano Cavara, professor of botany in the University at Catania.— Dr. Otto Conheim, extraordinary professor of physiology in the University at Heidelburg.— Dr. E. B. Copeland, chief botanist of U. S. Philippine Commission.— Dr. Lucien Louis Daniel to the chair of agricultural botany in the University of Rennes.— Dr. L. Detre, docent for bacteriology in the University at Budapest.—Dr. Karl Diener, extraordinary professor of paleontology in the University at Vienna. — Dr. Francis A. Dixon, professor of anatomy in the University of Dublin. — Dr. Hermann Dürck, extraordinary professor of anatomy in the University at Munich.— A. D. E. Elmer, botanical collector to the U. S. Philippine Commission.— Dr. C. H. Gordon, acting professor of geology in the University of Washington.— Dr. D. Hepburn, professor of anatomy in University College, Cardiff.— Dr. Thomas Jehu, lecturer on geology at the University of St. Andrews.— Dr. H. S. Jennings, assistant professor of zoölogy in the University of Pennsylvania.— Dr. H. P. Johnson, associate professor of bacteriology in the University of St. Louis.— Dr. J. N. Langley, professor of psychology in the University of Cambridge.— Dr. A. G. Leonard, professor of geology in the University of North Dakota.— Osmond E. Leroy, of the Canadian Geological Survey, geologist to the Chinese department of Mines.— Mary Isabel McCracken, instructor in bionomics in Stanford University.— Dr. Burton D. Myers, instructor in anatomy in Indiana State University.— Dr. Bohumil Nemec, extraordinary professor of plant anatomy in the Bohemian University at Prag.— Wilmon Newell, State entomologist of Georgia.— Edith M. Patch, entomologist in the Maine Experiment Station.— E. C. Perisho, state geologist and professor of geology in the University of South Dakota.— Dr. Augustus Pohlman, assistant professor of anatomy at the Johns Hopkins University.— Dr. Pompeckj, extraordinary professor of paleontology in the University at Munich. — Dr. Peter Potter, associate professor of anatomy in St. Louis University. — R. C. Punnett, demonstrator of comparative anatomy in the University of Cambridge.— Prof. W. M. Scott, pathologist to the Bureau of Plant Industry, U. S. Dept. of Agriculture.— Dr. J. R. Slonaker, assistant professor of physiology in the Stanford University.— Robert E. Snodgrass, instructor in entomology in Stanford University.— A. I. leSouef, director of the Zoölogical Garden at Sydney.— Dr. Percy G. Stiles, instructor in physiology in the Massachusetts Institute of Technology.— Dr. Franz Stuhlmann, director of the biological agricultural Institute at Amani, German East Africa.— Prof. J. W. Toumey, director of the Yale botanical garden.— Dr. Armin Tschermak, extraordinary professor of physiology at Halle.— Dr. Alfred Ursprung, docent for botany in the University at Freiburg, Switzerland.— Dr. A. F.

Wilder, professor of geology in the University of Iowa.— L. L. Woodruff, assistant in biology in Williams College.

RETIREMENTS.

Dr. Howard Ayers, from the presidency of the University of Cincinnati at the end of this college year.— Prof. Arnold Dodel, from the chair of botany in the University at Zürich.— Homer H. Foster, from the chair of botany in the University of Washington.— Dr. A. Hansgirg, from the chair of botany at Prag, after forty years incumbency.— W. M. Scott, from the position of entomologist to the state of Georgia.— J. E. Todd, from the professorship of geology in the University of South Dakota.

DEATHS.

Dr. Eugen Askenasy, honorary professor of botany at Heidelburg, aged 58.— Dr. Franz Bauer, docent for geology in the Munich Technical School, by a fall from the mountains near the Tegernsee, June 21.— John Allen Brown, archaeologist, at London, Sept. 24, aged 72.— Cornelius Van Brunt, botanist, at New York, Oct. 1, aged 76.— M. A. Certes, zoölogist, at Paris.— M. Meunier Chalmers, professor of geology in the Sorbonne.— Mr. Augustus Radcliffe Grote, the well-known entomologist, at Hildesheim, Sept. 23.— Prof. Karl Haussknecht, botanist in Weimar, July 7.— Alexander von Homeyer, ornithologist and entomologist, in Greiswald, July 14, aged 70.— Dr. C. T. Hudson, the well-known student of rotifers.— Prof. Emond Nocard, director of the veterinary school at Paris, and author of works on parasitic diseases of animals, Aug. 3, aged 54.— Dr. A. G. Ohlin, docent for zoölogy in the University at Lund, July 12, aged 36.— Dr. Alphonse Renard, professor of natural history in the University at Ghent, July 9, aged 60.— Professor Alexander Rollett, physiologist of the University at Graz, Oct. 1, aged 69.— Dr. Frank Russell, anthropologist, an associate editor of this journal, and formerly instructor in Harvard University, in Arizona, Nov. 7.— Carl Wüstnei, an ornithologist of Mecklinburg, Dec. 21, 1902.

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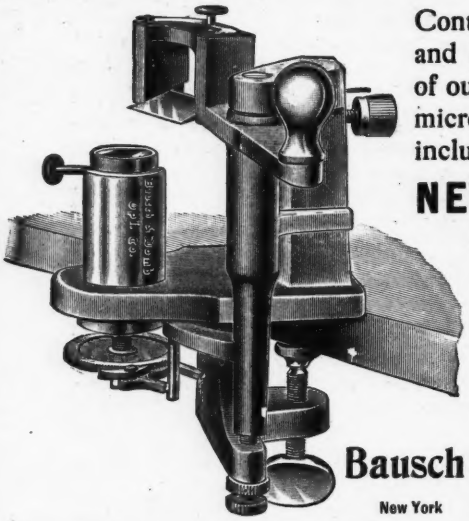

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